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# JOURNAL

## OF THE SOCIETY OF

# MOTION PICTURE ENGINEERS

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# JOURNAL

## OF THE SOCIETY OF

### MOTION PICTURE ENGINEERS

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## THE NEW WALT DISNEY STUDIO\*

W. E. GARITY AND J. L. LEDEEN\*\*

**Summary.**—This article describes the planning and construction of the world's largest animated motion picture studio, explaining the routine and the problems encountered in production of these pictures, together with the facilities provided in the new plant for solving these problems. The studio is unique in that it was built from scratch on a vacant plot of ground with no restrictions by existing facilities to hamper planning. It is comprised of some twenty buildings on a 51-acre plot and includes, among other things, one of the most complete air-conditioning plants in the country.

The striking success of Walt Disney's feature-length cartoon *Snow White and the Seven Dwarfs* proved conclusively that there was a definite demand for pictures of this type, and that, if they were pictures of quality, they would not only be accepted but could be produced at a profit. The recognition of this fact prompted the Disney Studio to launch an augmented program of feature productions which resulted in the release of *Pinocchio* early this year and the introduction to the public this fall of a new musical feature called *Fantasia*. The year 1941 will see a further increase in the number of features released.

Augmented production schedules bring with them problems of expansion. They require increased personnel, more space, enlarged facilities, and smoother production flow lines. During the era prior to the release of *Snow White* the studio averaged eighteen to twenty short subjects in work all the time, and it required seven to nine months from the beginning of actual production until the picture was shipped. With that experience on short subjects it must be clear that on a program of feature production it would be necessary to have a proportionate number of features in work, depending on the release schedule.

If a program of one feature a year were contemplated, it would be necessary to have three features in work—one starting, the second in

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\* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received November 1, 1940.

\*\* Walt Disney Productions, Burbank, Calif.

animation, and the third in the finishing stages. This would result in a two-year production period for each picture. If the release schedule were to be increased to two a year, there would have to be six features in process of production at one time. The only way to reduce the amount of work in progress at any one time would be to shorten the production schedule per picture, and this can not be dictated arbitrarily since the work involved is largely creative and can not be accelerated at will like other activities. The type of story, the type of characters, and the number of characters are all factors in determining the length of the production schedule.

When the studio decided to launch its program of feature production, steps were taken immediately to enlarge the studio facilities. An attempt was made first to redesign the Hyperion Plant, but after



FIG. 1. View of new Disney studio, from nearby hillside.

considering the long period of construction that would be necessary to revamp the plant and all the attendant confusion and disruption of production that such construction work would cause, it was decided to abandon the old plant and make a fresh start in a new location.

After considerable study, the present site in Burbank at the edge of Griffith Park was selected. The plot consists of fifty-one acres of land and on it, without restrictions of any kind, the studio engineers designed a plant suitable for the specific and specialized needs of the organization. (Figs. 1, 2, and 3.)

#### HOW CARTOONS ARE MADE

The general process of making animated cartoon pictures is now fairly well known to most people, but a brief review of some of the

finer details may be helpful in giving a more complete understanding of the reasons behind some of the features designed into the new plant at Burbank.

The first step in the production of a cartoon is the selection of a suitable story and development of the necessary characters. For this purpose the studio maintains a sizable staff of story experts whose function it is to review existing stories, write new ones, and do detailed story research work. Sketches are prepared to illustrate the action which is involved and the artists start developing their conceptions of the characters who take part. Characters in a cartoon



FIG. 2. View down "Minnie Mouse Blvd." showing, on the left, Inking and Painting, Camera, Cutting, Shorts, and Live Action Buildings, and on the right the Animation Building.

frequently go through quite a process of evolution before the final conception of the character is reached.

Once the story is settled and the characters defined, the picture is ready for animation. Each picture has a director assigned to it and his function is the coördination of all production details.

The animation of the action is first rendered in pencil by a staff of animators, assistant animators, and "inbetweeners," who have various sequences of the picture assigned to them by the director. Any time during the course of production the animator is at liberty to send a series of drawings to the Test Camera Department where the drawings are photographed in continuity. The film is developed in negative form and the tests thus developed are spliced in a loop.



This test-film and the drawings are then returned to the animator who is provided with a moviola on which he can run this test loop to check the animation and make whatever changes that occur to him.

When these test loops have been approved by the animator, they are delivered to the Cutting Department where the test is cut in continuity and synchronized with the sound-track of the production. Each director reviews such tests from each of his pictures once a week in a small review room equipped with sound. When all the test animation is complete so that a complete picture is available in test form, the test animation reels are previewed by the studio at large in



FIG. 3. View of Dialog and Sound Effects Stage and Animation Building.

a theater. It has been found from experience that the reaction of the studio group at these showings parallels very closely that of the average theater audience. It is therefore possible in this manner to anticipate general audience reaction to pictures while they are still in the early stages of production, and to make whatever changes might be indicated without excessive expense.

When the animator's drawings are completed and approved, they are delivered to the Inking and Painting Department where they are traced on celluloid sheets. Following the tracing of the outlines, the entire areas of the characters are painted in full color. This department is operated entirely by girls who perform all the operations in this stage of the process. Operating in conjunction with the Inking

and Painting Department is the Paint Laboratory, where paints are mixed, studied, and classified; and the Process Laboratory, which at the present time is more or less of an experimental institution, whose function may be described best as the study of special processes for eliminating "jitter" from the animated pictures.

When the inking and painting of the celluloids has been completed, they are sent, together with the proper background paintings, to the Production Camera Department where each picture is photographed in proper relation to its background and in proper sequence for animation on a reel of sensitive film which, when printed and run at proper speed through a projecting machine, will give the intended animation to all the characters. The exposed film is sent out for developing and upon its return is turned over to the Cutting Department for insertion in the final master reel.

Of course, this studio, like live-action studios, requires extensive facilities for recording sound. Practically all pictures require special sound effects of various sorts. All pictures have various musical themes running through them and contain dialog, vocal, and instrumental sequences. For the recording of music and effects the studio needs and has adequate facilities in the form of recording stages, monitor booths, recording equipment, and a re-recording set-up.

#### DESIGNING THE NEW STUDIO

The old Disney plant at Hyperion grew "like Topsy" and many planned developments and improvements there were handicapped by unavailability of property when needed. So as a result there could be no well ordered program of expansion laid out at that site. At the new studio, the staff had the advantage of starting from scratch. There were no existing buildings or utilities to hamper the planning and in this respect the new plant is probably unique in the history of motion picture studios. A detailed study was made of the studio's needs, and then, practically without restriction, a plant was built to fill those needs.

It might be said that the uppermost thought in the minds of those who designed the new studio was to produce facilities for optimum per capita production. The intent was not to design a plant at lowest possible initial cost, but to provide at reasonable *total* cost whatever facilities, space, and organization increased production would justify. Emphasis was placed on steps to restrict maintenance

cost and operating cost in the new plant, and wherever reasonable initial expenditure promised to curtail operating overhead, that expenditure was made.

The first consideration was to provide a smooth and efficient production flow line—a sort of picture assembly line. One building was set aside for the complete creative function from beginning to end. This building is properly named the Animation Building, and in it are the story departments, directors, layoutmen, animators, assistant animators, and inbetweeners, the latter three doing the main part of the job, the absolute creation of the animated picture. Across the street from the Animation Building, and connected with it by an underground all-weather passage, is the Inking and Painting Building, from which branch the Paint Laboratory and the Process Laboratory, housing activities that are supplemental to the Inking and Painting process. From the Inking and Painting Building the production flow line continues smoothly past a checking unit into the Camera Building, and just beyond the Camera Building, in logical progression as to function, lies the Cutting Building, which represents the terminus of the process.

Three recording stages are provided: one for orchestra, one for dialog, and a third for sound effects. These stages, together with a theater, are arranged so that they are adjacent to both the Animation Building and the Cutting Building. A large live-action stage is provided for special studies, and a restaurant has also been provided.

Three definite requirements for specific internal conditions in these buildings pointed to the need for an extensive air-conditioning plant on the lot. First was the need for scrupulous cleanliness in the buildings. At the old studio considerable trouble had been experienced in the Inking and Painting, Camera, and Cutting Departments because of inadequate control over the cleanliness of air and quarters. When it is considered that a slight speck of dust under the glaring lights of the cameras can produce undesirable effects, the necessity for scrupulous cleanliness becomes apparent. In the new studio, it was planned to attack this problem from three angles: to use sealed windows and weather-stripped doors wherever possible to keep dirt out, to avoid drapes and carpets in those buildings where dust and lint were a problem, and to provide complete air-conditioning for the maintenance of clean air.

The second problem at the old studio had been the lack of control over atmospheric humidity. Inasmuch as paints used in making



these pictures are water paints, their rate of drying and the condition of the pictures after the paints have dried are both very dependent on the humidity of the air. If the air is too dry, the paints crack and chip off the celluloid, and if the air is too humid, the paints become tacky and smear. In the past these problems have necessitated frequent reworking of scenes and adjustment of paint formulas. In the new studio it was planned to have controlled air-conditioning so as to permit the stabilization of paint formulas and the reduction of losses.

The third requirement was the simple need for comfort. In the San Fernando Valley temperatures have been recorded as high as 109 degrees, and when it is considered that approximately ninety per cent of the cost of a finished picture consists of labor, and that in this category about seventy per cent of the labor is exclusively creative, the vast importance of ideal working conditions is easily recognized, since to keep a man comfortable is to keep him productive.

The importance of adequate light in any office building has always been appreciated, but in an office building which consists of over three hundred artists' studios adequate lighting is doubly important. With this in mind, the rooms in the Animation Building and Inking and Painting Building were planned so that every artist was in an outside room, that as many rooms as possible would have north light, giving a maximum of light without glare, and that all rooms facing in other directions would be equipped with adjustable shutter awnings admitting light from the sky but barring glare from the sun.

In keeping with the concern for employees' comfort and adequate lighting, thought was given to the provision of exercise and recreation facilities. Plans in this respect are not yet entirely complete, but it may be mentioned that there have been provided on the roof of the Animation Building a gymnasium, sun-deck, steam room, massage room, and other facilities for the employees. Art is a sedentary occupation and does not provide much opportunity for exercise. A gymnasium which helps the men keep fit can not be considered in the light of a luxury, but must be regarded as a necessary production tool. Further extension of exercise and recreational facilities on the lot are planned at a later date.

At the old studio at Hyperion there was a recognizable lack of a suitable theater or auditorium for reviewing animation test reels, previewing pictures, and holding special study groups. The sound stage at the Hyperion Studio was a sort of "catch-all" for sound

recording, theater functions, re-recording, and all other activities that required a large auditorium space. In planning the new studio it was decided to untangle these conflicting activities and build a separate theater, distinct from the sound stages. This would make it unnecessary to interfere with set-ups on the sound stages and would thus eliminate interferences with production, at the same time providing a review room and an excellent place for re-recording music, dialog, and sound effects on their final sound-tracks, since the re-recording mixers would hear the sound in an actual theater at the final re-recording.

Past experience with the studio's activities had indicated the importance of flexible designs that could accommodate themselves to expansion. Starting from scratch, therefore, in the planning of all the structures, underground utilities, storm sewers, sanitary sewers, water facilities, electric facilities, *etc.*, provision was made to accommodate a certain amount of predetermined expansion in all the buildings on the lot that were likely to expand, and also to allow for expansion of these facilities to areas of the lot yet unused. This meant, of course, that future needs had to be estimated, pipe sizes made adequate, streets planned, conduit and piping arranged for easy expansion without interfering with current operation, *etc.* It can be said that as far as it has been possible for the studio engineers to anticipate the future expansion, provision has been made to accommodate it.

Especially careful consideration was given to providing facilities which would tend to reduce maintenance and operating cost of the plant. In general, as one makes machinery more accessible and automatic in its operation, one tends to reduce the amount of time that has to be spent in its care and attendance. In the air-conditioning plant alone on this lot there is a considerable investment in machinery in the form of fans, motors, compressors, automatic controls, boilers, heat exchangers, and other equipment of this type. Considerable care has been taken in the design of this plant to provide adequate access doors, to make things easily removable for repair, to provide suitable indicating devices giving a quick check on plant operation, to furnish servicing facilities and working quarters that require minimum steps on the part of the operator and minimum time to get things done. This is true not only of the air-conditioning plant but of the electrical facilities, plumbing facilities, and fire-protection system. For the amount of equipment on this lot, the

size of staff required to care for it is considered small, and the resulting operating and maintenance costs are correspondingly low.

#### THE ANIMATION BUILDING

A primary concern in the Animation Building being the provision of adequate light for all artists, the building was arranged in the form of eight separate wings connected to a central corridor, oriented on a true North-South axis. Each wing is three stories high, and in every wing floor the offices are arranged on either side of a wing corridor in such fashion as to make every office an outside room. This arrangement gives a maximum of rooms with true north light. Rooms facing other directions of the compass are provided with a specially designed Venetian-type awning with counter-balanced blades remotely adjusted from inside, permitting the artists to set the blades for maximum light from the sky with elimination of glare from the sun.

The arrangement of the building in eight separate wings served another purpose beside the provision of light. Southern California being in the so-called earthquake belt, and the Animation Building being a structure some 250 feet long, it was desirable to separate it structurally into several units which, though integrated into the structure as a whole from the functional standpoint, could weave harmlessly as separate structural units in the event of seismographic disturbance. Each wing has, therefore, been constructed as a separate structural unit, connected to the central section by a copper expansion joint. The central section itself, because of its length, has been divided into two distinct structural units, making a total of ten structural units in this one building. Incidentally, the division of the building in this fashion made it possible to provide, at the junction points of wings and central sections, eight vertical shafts extending the full height of the building, perfectly located to carry the extensive system of air ducts included in the air-conditioning plant, as well as the fire-protection piping, the air-conditioning control tubing, and other facilities.

The production flow line in the Animation Building starts logically at the third floor and works downward toward the ground. The third floor is occupied largely by the Story Department whose function has been described previously, and the Character Model Department, whose function it is to develop story characters by sketches, paintings, and three-dimensional sculptured models. Also, on this



floor are two large review rooms, each accommodating about fifty people, used mainly for the study of pictures by large groups, and also for story conference purposes. It is here, too, that Walt Disney has his office, since he functions very actively in the conception and development of every picture that is turned out.

On the second floor, which is devoted to the direction units, each wing floor houses two direction units. Each unit consists of a suite of four rooms, accommodating the director, assistant director, layout artist, and secretary. Each two direction units are provided with a small review room, accommodating about ten people, for the purpose of projecting and checking the animation tests and test reels. These smaller review rooms use moviola projectors in place of standard projector machines, the moviolas being located in a booth adjoining the review room, and operated by a remote console from the review room. These smaller review rooms, incidentally, are called "sweat-boxes," a name given to them at the Hyperion Plant in a day when the rooms used for these purposes were stuffy, unventilated rooms which, when crowded with a group of animators, were truly and literally "sweatboxes." Of course, in the present air-conditioned plant the term has lost its original significance, but nevertheless continues to be used for sentimental reasons.

The first floor of the building is devoted exclusively to the animation function, each room being designed to accommodate three men. The animator usually occupies a room by himself, with assistant animators and in-between artists occupying adjoining rooms.

On each floor, in each wing, there is provided a reception desk immediately off the main corridor. At these reception desks are employed girls who operate as secretaries to all the artists in that particular wing. Each girl operates a small telephone switchboard, and monitors all calls being made. She controls the door to the wing in order that no one may interrupt the artists without first being announced. She receives and checks all materials passing to and from the wing. It is also her function to maintain records of the movement of materials between departments, and to keep time records, which are later used in cost analysis and control of production.

The basement of the building is devoted to service functions. It is here that the Test Camera Department is located, with all necessary facilities for producing quickly test-films of the animation. Here too one finds the central telephone exchange, electrical shop, furniture storage, and all air-conditioning equipment serving this building.

Other facilities available in the building are a library, in which the studio endeavors to keep the latest works available on subjects of interest to the studio staff, and a coffee shop, which provides room service to the artists, as well as counter service.

Careful thought was expended not only on the design of structure and arrangement of rooms, but also on the furnishings and interior decoration. All the furniture in this building was specially designed and built to meet the needs of the studio. Obviously, the require-



FIG. 4. Some of the special desks developed for the use of the artists.

ments of furniture in an animation studio are so specialized that nothing in the way of standard equipment available on the market is quite adequate to fill the need. It was found necessary, therefore, to make functional studies of an animator's activity, and to design furniture so arranged that the animator could perform his work with minimum waste time and motion. All furniture in the studio is modern in design and tone (Fig. 4).

Aside from functional furniture, efforts were made to keep the artists at ease and comfortable by providing their rooms, wherever possible, with adequate carpeting, drapes, and interior decoration. The



entire interior of the building was painted in harmonizing pastel tones, designed to furnish restful atmosphere. The purpose of carpeting and drapes is not alone ornamental, but serves to impose quiet on the artists' rooms. To this end, also, all ceilings in the building have been finished with acoustic plaster, to give further deadening effect, and even the light switches on the wall are of the new silent type recently developed.

Inside, the building is kept comfortable at all times by one of the most complete air-conditioning systems in the country. Air is brought into each room at the center of the ceiling through a specially designed combination air outlet and electric light fixture, designed especially for this installation, and never used elsewhere before. This unit has been designed so as to permit independent regulation of air quantity and direction, and to spread the air uniformly in a thin diffusing sheet across the ceiling. It is a pleasure to be able to report that with this unit completely draftless distribution of air has truly been achieved.

Removal of vitiated air in the room is accomplished through another unique air outlet which is built into a fixture accomplishing a dual function. Around the entire outside periphery of the building, on each floor, there has been installed a continuous air-electric base, approximately a foot high and four and a half inches deep. The lower part of this base is an air duct, broken up into separate sections for each room, having a stamped louvered face and connected through the floor into an exhaust air trunk. The upper part of the fixture is a dual electric conduit, continuous around the building, with a removable face permitting the introduction at any time of extra telephone lines, small power lines, compressed-air lines, or other facilities that might be required. Through the use of this conduit, it is possible to introduce such facilities without the necessity of cutting walls or breaking building structure. With this same thought in mind, all ceilings in the building have furred spaces approximately two feet deep above them, providing a permanently accessible space for the servicing of air ducts, sprinkler lines, electric conduit, and other facilities.

The Animation Building, oriented as it is to all points of the compass, and containing as it does numerous special conference rooms, rooms with heat-generating machinery in them such as projection booths, and rooms that are sources of heat and odor, like the coffee shop, presented a rather difficult air-conditioning problem. To solve

this problem it was felt necessary to do a very complete job of zoning the controls so as to make conditions in the building independent of the position of the sun and independent of the movement of large bodies of personnel from one room to another.

To this end, the building has been zoned systematically and thoroughly with respect to all these factors, resulting in a total of 163 separate zones of control, so flexibly arranged that it is even possible to heat any of these zones at the same time that refrigeration is being provided for any other zone. Air temperatures in the building are never permitted to go below 74°F, which seems to be the temperature desired by most of the occupants of the building. As the outdoor temperature rises during hot weather, the inside temperature is automatically increased until it reaches a maximum of 78° at an outdoor temperature of 100°. Relative humidity in the building is maintained between 40 and 50 per cent. An item of incidental interest is the fact that the four projection booths in the building, housing considerable heat-generating equipment, are all completely air-conditioned for the comfort of the occupants.

A most unusual feature of the air-conditioning system in the Animation Building is the provision of 100 per cent conditioned outdoor air, without any recirculation whatsoever. Ordinarily a plant taking this amount of outdoor air without recirculation would be prohibitively expensive to operate. Fortunately, on the site of the new studio, there is available underground an almost limitless quantity of clear well water, which remains at a temperature of approximately 67°F all year round. This underground sea of water has been tapped by two wells, each delivering 2600 gallons per minute, and the well water is employed in the air-conditioning plant for pre-cooling the air in summer, and pre-heating it in winter. The use of well water in this fashion greatly reduces both the initial cost and the operating cost of the air-conditioning plant, which is thus privileged to employ outdoor air in such large quantities, and without penalty. After nine months' work in this finely ventilated and odorless building, the studio feels that the decision to ban recirculation of air was a happy one.

#### INKING AND PAINTING BUILDING

The three primary considerations in the design of the Inkers' and Painters' building being light, comfort, and cleanliness, the Inking and Painting rooms have all been arranged so as to receive north

light only, and through large areas of window. Furthermore, all working rooms have linoleum floors and lintless interiors, and windows are sealed to prevent the entrance of dust during the occasional dust storms to which the valley is subjected. Each work room is separately air-conditioned, being provided with 100 per cent conditioned outdoor air without any recirculation whatsoever, resulting in a low odor level in spite of the great predominance of volatile paints and odorous chemicals in these rooms. Each work space is independently controlled as to temperature and humidity continuously, the temperature being maintained in the same brackets as in the Animation Building, and the humidity being maintained at a constant value of 50 per cent.

As an adjunct to this building there is provided a lounge, private restaurant, and sun-deck, available only to the girls who work in this building, and designed to afford rest and relaxation from the meticulous and exacting work they do. Lounge and restaurant are completely air-conditioned.

In addition to the actual working spaces where the Inking and Painting processes are carried out, the building also houses supervisory offices, checking rooms where the production output is examined before being passed on to the Camera Building, and a Paint Laboratory which makes all production paints, experiments with new colors, and carries on miscellaneous paint research. This laboratory has already classified and cataloged over 2000 different colors used in the studio's work.

The provision of pure north light for each of the eight work corridors necessitated the leaving of open areas between alternate pairs of corridors, and these areas have been utilized to provide pleasant landscaping and flower beds which lend a friendly aspect to all rooms which open on them.

#### THE PROCESS LABORATORY

The Process Laboratory was one of the most difficult on the lot to design, inasmuch as its functions are principally experimentation in photography and film processing methods, with the result that the designers were confronted with the problem of designing a building for future production methods which at the time were only vaguely suggested.

Both the piping and air-conditioning systems in this building are particularly complicated. There is not much that can be said about



these matters except to point out that water is required in many parts of the building at several different temperatures simultaneously, thus introducing problems of refrigeration and heating. Distilled water is distributed throughout the building, making necessary the use of corrosion-proof piping, in this case aluminum. Chemicals are used in great profusion in the experimental processes, making necessary the employment of stainless steel and rubber in the tanks, piping, and pumps employed in this connection. The air-conditioning had to be arranged to provide for fume removal at points of maximum chemical concentration, with ducts constructed to resist corrosion. Lead-clad steel sheets were used to construct corrosion-resisting duct work, and fans handling corrosive fumes were painted internally with asphaltic paint.

The building had to be designed so as to permit expansion and possible rearrangement in floor space and facilities, and to this end piping was designed so it could be extended easily. Fans were selected to handle increased air quantities, if needed, and duct work was arranged to accommodate additions in space served.

#### CAMERA AND CUTTING BUILDINGS

One of the keynotes of design in these buildings was cleanliness, and therefore, as in the Inkers' and Painters' building, windows are sealed, floors are waxed, no carpeting or drapes are employed, and doors are weather-stripped as protection against occasional dust storms. Furthermore, both buildings are carried under a slight internal air pressure, so that air leakage, if any, is outward rather than inward.

In the Camera Building an additional problem arose from heat generated by lamps on the cameras. At the present time the building contains two standard cranes and two multiple plane cranes. Each of the latter is served by a 75-kw d-c generator, driven by a 125-hp induction motor. With the possibility of anything up to 75 kw being dissipated within a camera room 25 feet wide by 28 feet long by 16 feet high, it is clear that special provision had to be made to remove this heat. To accomplish this, special housings were designed for the lamps and so arranged as to take a constant stream of cool room air past the lamp bulbs and out an exhaust duct to atmosphere. This not only keeps the lamps cool and increases their life, but also decreases the amount of refrigeration required for maintaining comfort in the building (Fig. 5).



A unique feature of the Camera Building is that both men and materials entering the camera rooms are pre-cleaned. All persons entering the building have to pass through a special de-dusting chamber in which they are exposed to air blasts from twenty separate nozzles, directed against the clothing in such direction and at such velocity as to remove the bulk of the lint and dust picked up from outdoors. Painted celluloids entering the building from the Inking and Painting Department first enter a special cell-cleaning room where the

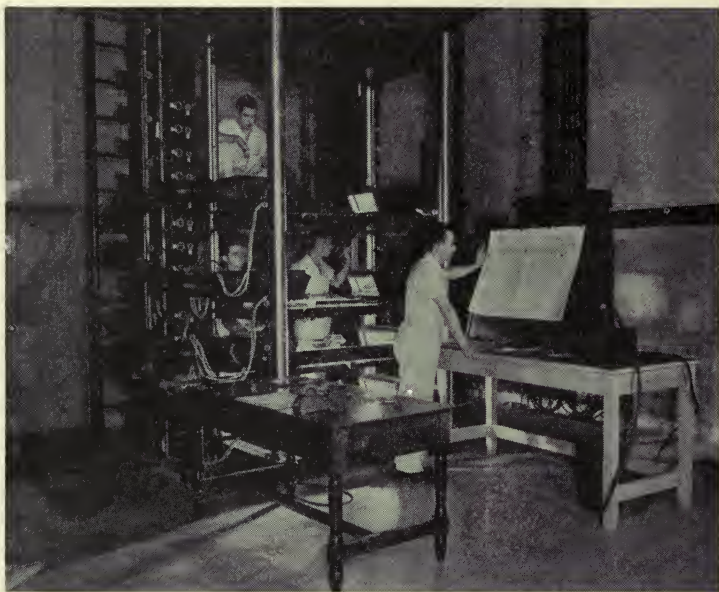


FIG. 5. One of the cameras in the new Camera Building.

“cells” are first treated to discharge the static electricity which tends to accumulate on them, and are then brushed to remove the dust which had adhered by virtue of the electrical charge carried by the cells.

Another feature of the air-conditioning system in the Camera Building is the employment of exhaust air from the building to cool the camera generators on its way to outdoors. This has been done by casting in the floor of the generator room a concrete tunnel connected at one end to the discharge from the main exhaust fan, and opening at various points along its length under the motors and

generators, thus directing a blast of air against these machines. An atmospheric relief in the ceiling of the room allows the exhaust to pass to outdoors.

The Cutting Building has few features of unusual interest. It is naturally a fireproof structure. In addition to the regular cutting and splicing rooms and supervisory offices, one room has been set aside for the running of sound-track. This room contains dummy sound heads, and all sound-tracks received from the laboratories



FIG. 6. Scene on Sound Effects Stage.

are set up and run in this room, the sound being piped from here to any one of a number of locations on the lot that have been set aside for listening. Circuits are provided so that this sound may be reproduced in any of the directors' rooms, in the theater, and in certain rooms in the Story Department. By setting up to run sound-track in this manner, the studio is assured of maintaining sound-tracks in good physical condition, since it eliminates transportation and handling, and insures preservation of the film in a clean atmosphere at constant temperature and humidity.

Both the Camera and Cutting Buildings are provided with 100 per cent conditioned outdoor air, with no recirculation. The absence of recirculation in these buildings is a fire and fume protection, as well as an addition to comfort. The Cutting Building, furthermore, has all supply and exhaust air grilles equipped with fire dampers and damper guides, built integrally with the grille frames and arranged with fusible links so that a fire in any room will immediately shut off the air supply and exhaust from that room.

#### THE STAGES

Because of proximity to the Union Airport in Burbank, it was felt necessary to take particular pains with the acoustic insulation of the stages in which dialog, music, and sound effects were to be recorded. Accordingly, it was decided to adopt the principal of construction sometimes referred to as "building within a building." In other words, these stages are constructed with double walls, the inner wall being entirely separate from the outer, and the ceiling of the room resting on the inner wall structure and having no connection with the outer. Both walls and ceiling are naturally provided with adequate layers of both hard and soft insulating materials to give the desired noise reduction. Acoustic absorption of the walls in the Orchestra Stage, for example, has been measured as 52 decibels for sound coming from a gasoline-engine-driven tractor, and 70 decibels for a standard automobile horn (Figs. 6 and 7).

The Orchestra Stage has been provided at one end with a hardwood orchestra shell constructed with diverging convolutions of such shape as to direct sound from the shell toward the microphones. The reverberation time on this stage is approximately one second, and is practically flat at all frequencies, the variation being less than 1 decibel.

Each of the three recording stages has its individual recording channel immediately associated with it.

Air-conditioning systems for the stages naturally had to conform to severe acoustic specifications laid down for the stages themselves. In order to keep the air-conditioning systems quiet, fans were selected to operate at low speeds, ducts were sized so that nowhere did velocities exceed 700 feet per minute, elbows were curved and sharp corners avoided, and insulating materials were employed strategically in sound-traps to prevent fan noises from passing into the stages and thus to microphones.



## THE THEATER

The need for a theater has been discussed in an earlier section of this article. The structure set up on the Disney lot for this purpose is a 622-seat house of concrete and wood construction, housing, in addition to the theater and projection booth, a re-recording room in which are set up the dummy sound-heads employed in the re-recording operation. Immediately adjoining the dummy room is located a recorder used exclusively for the production of final sound-track negatives.



FIG. 7. Scene on Orchestra Stage, showing convolutions of orchestra shell designed to improve acoustics.

In the center of the house is a console for use by the re-recording mixers, containing the necessary mixing panels and volume indicators. This console is built in such fashion that it does not interfere with the visibility of any seat in the house, and yet gives the mixers an opportunity to sit in the center of the theater while listening to the sound coming from the speakers. The theater is built with walls of acoustic plaster arranged in panels so oriented as to control the reflections of sound. This theater has somewhat less reverberation than the average theater, but was intentionally constructed so because during the re-recording operation the house is practically empty, and it is necessary to have a less reverberant auditorium to compensate for the absorption normally introduced by an audience.



The dummy room in the theater is also piped into the same sound channels on the lot as the special dummy room in the Cutting Building, thus permitting sound-tracks to be run in the theater and reproduced in many other places on the lot. Furthermore, although the sound recorder in the theater is ordinarily the only one used in the re-recording operation, sound channels are installed connecting the recorders in the various sound-stages with the theater to permit special recording operations when desired.

#### THE RESTAURANT

Due to the fact that inadequate eating facilities are available in the vicinity of the new studio, it was felt necessary to provide on the premises a suitable restaurant to accommodate the employees. The structure erected for this purpose is a frame and stucco building containing one large dining-room seating approximately 400 people, in which only table service is available, and a smaller room housing a 67-stool counter in which only counter service is available. A small short order kitchen is provided behind the counter, but in general most food is prepared in the main kitchen, which serves both dining-rooms.

The kitchen is equipped with every facility to be found in a modern restaurant kitchen, the desire being to provide for the employees high-class food at moderate prices, even though it proves necessary for the studio to absorb part of the expense needed to accomplish this. Refrigerated walk-in boxes are provided for meats, vegetables, and dairy products, and refrigerated reach-in boxes for salads, pastries, and other foods.

Both dining-rooms are completely air-conditioned, using 100 per cent conditioned outdoor air with no recirculation. This policy has made possible, in the restaurant, the exhausting of conditioned air from the dining-rooms through the kitchen proper, the exhaust taking place through ample exhaust hoods located strategically over the ranges, coffee urns, bake ovens, dish-washing machine, and other sources of heat generation. All windows in the kitchen are sealed and all doors are kept closed, with the result that the kitchen is kept almost as comfortable as the dining-rooms themselves.

#### AIR-CONDITIONING PLANT

The design and construction of this studio was favored by the fact that starting from scratch the buildings, the facilities within them,

and the utilities that serve them were all designed simultaneously, thus permitting adjustments and compromises to be made during the process of design and avoiding many problems and complications later.

This was especially true of the air-conditioning plant, since the General Electric engineers who designed the air-conditioning and supervised its installation were privileged to work with the architects and structural engineers from the moment they first began to set plans on paper. Building structures were thus laid out to accommodate air-conditioning needs, and air-conditioning designs were adjusted to meet structural requirements, with the final result that the plant as a whole represents a well integrated and coördinated entity.

As a starting point in the design of the air-conditioning plant, buildings on the lot were divided into two groups—those that have *continuous* usage, such as the Animation Building, Inkers' and Painters' Building, Camera Building, and so forth; and those buildings which have *intermittent* usage, such as the theaters, stages, and restaurant. Stages may sometimes be shut down for weeks at a time, thereby not requiring air-conditioning during that period. The buildings in the first group, however, operate every day of the week and require continuous service from the air-conditioning plant. It was decided, therefore, to serve the buildings in the first group (continuous usage) from a central heating and refrigerating plant, whose heating and cooling facilities would be piped through water mains to the buildings in this group. The second group of buildings would be served by individual plants located within the buildings proper, having no connection with the Central Plant, so as to facilitate the shutting down of these buildings at any time desired without compromising the operation of the Central Plant.

The Central Plant building, located between the Inkers' and Painters' Building and the Camera Building and slightly to their rear, lies very close to the center of the load it serves and is a reinforced concrete structure, 40 × 175 feet, two stories high. The rear of the building is a large boiler room, and the front of the building a compressor or refrigeration room. In the center of the building, athwart the cooling and heating plants, lies the operating engineer's office, provided with double glass panels on all sides so as to permit a view of practically all the equipment in the building from the quiet interior of the office. In this office are kept various indicating and recording devices showing temperatures of heated and refrigerated

water, steam consumption, outdoor wet and dry-bulb temperatures, and other such items of interest in plant supervision. Also mounted in this office is an indicating panel of colored lights wired to show the operation of the 135 fans in the various remote fan rooms on the lot, and providing telephone circuits to permit two-way conversation between the office and any fan room.

The boiler room contains two 190-hp water-tube boilers, generating steam at twelve pounds' pressure. These boilers are normally gas-fired under completely automatic control, with standby equipment for burning oil under manual control. Part of the steam produced is passed into heat exchangers, where the heat is imparted to the water in a circulating loop which provides heat for all the buildings served by the Central Plant. The balance of the steam produced is piped directly to the fan rooms where it is injected through perforated copper tubes under automatic control into the air streams, to give regulation of humidity at such times as needed. With the large quantities of outdoor air employed in this air-conditioning plant, and the extreme dryness which the outdoor air reaches on many occasions (15 grains of moisture per pound of air) the humidification requirements on the lot are approximately 5500 pounds of steam per hour at peak load.

The evaporation of this quantity of water in any kind of humidifier would create a problem of disposal of salts of evaporation. In this plant the problem is solved simply by the use of water-tube boilers in conjunction with water filter and a Zeolite softener, together with a feed-water heating de-aerator. Both the liming of boilers and oxygen corrosion are thus prevented, and at the same time, having eliminated the necessity for use of boiler compound, the steam is kept absolutely odorless because it is pure and uncontaminated by foreign substances. Regular blowdown of boilers keeps down salt concentration in tubes and drums.

The boiler accessories, such as boiler feed pumps, condensate return pump, induced draft fans, and master control, are all electrically driven. The boilers are equipped with indicating pressure gauges, steam flow recorders, indicating draft gauges, and carbon dioxide and stack temperature recorders.

The compressor room really contains two separate refrigerating plants, one of them serving the Animation Building, and the other serving Film Row, as the balance of the group of buildings served by the Central Plant is termed. The reason for segregating these two



refrigerating plants is that air-conditioning for the Animation Building is shut down every evening and started every morning, whereas air-conditioning for Film Row, being required to preserve paints in good condition, is operated on a 24-hour day, 365-day a year basis. It should be noted, however, that whereas these two plants are separated for normal operation, cross-over connections are provided so they may be tied together in case of emergency.

The refrigeration plant consists of twelve 50-hp General Electric compressors, seven of them being connected to the Animation Building and five of them serving Film Row. Each compressor is connected to an individual Struthers-Wells water chiller, and the chillers in turn are manifolded together into a common chilled water system. The refrigeration circuit of each machine is absolutely separate from that of any other machine, thus limiting the danger of losing refrigerant through any leak which might develop. The refrigerant used is Freon-12, and the total amount required in this plant is approximately 2400 pounds, 200 pounds being needed for each machine.

Control of the compressors is fully automatic and is regulated from outgoing chilled water temperature, the compressors being regulated so as to turn themselves off or start themselves up automatically in order to maintain a constant predetermined chilled water temperature. Capacity of the plant is approximately 550 tons of refrigeration, or enough to cool 1650 gallons of water per minute from 55° to 47°F, which are the operating temperatures on the chilled water loop. Two 20-hp pumps circulate the chilled water through the Animation Building circuit, and two 15-hp pumps operate on Film-Row. At times during night operation one 50-hp unit is adequate for the dehumidifying requirements of Film Row.

Additional space is available in the Central Plant to accommodate any enlargement of plant capacity that might be dictated by expansion of buildings served from this plant. Piping leaving the Central Plant radiates in three directions. Running west, it crosses through a tunnel under the street to the Animation Building 250 feet away. Running north, it passes through a second tunnel into the basements of the Inking and Painting Building, Paint Laboratory, and Process Laboratory, which are all interconnected. Running south, it enters a third tunnel underneath the Camera and Cutting Buildings, and stubs off in such fashion that the Animation Shorts Building and Annex, moved over from the old studio, can be connected up to this plant.



In the Animation Building, which represents about 350 different rooms covering 150,000 sq-ft of floor space, conditioning of the air is accomplished in eleven different fan rooms. Eight of these fan rooms are somewhat identical in arrangement, each of them serving all three floors on one wing. Two of the remaining fan rooms are smaller in size and designed to accommodate rooms in the basement which are set aside for test camera activities, the telephone office, and the production cost department. The eleventh fan room is on the roof of the building, and serves the gymnasium quarters in the pent-house.

Inasmuch as one of the outstanding features of the air-conditioning plant is the zoning arrangement in the Animation Building, a brief description of a main fan room layout may be of interest. Outdoor air is taken into each wing separately through fresh air intakes located in the courts between wings, at second and third floor levels. This air is carried through a vertical shaft into the basement and first passed through a bank of air filters of permanent type, constructed of crimped galvanized wire arranged in sections of gradually decreasing aperture, and kept oiled with pure mineral oil of sufficient viscosity to scrub from the air all dust and pollen particles and other foreign bodies. Leaving the filters, the air enters the heat transfer surface of the well water coils which have a capacity in summer of cooling 100° air down to 75°F, and a capacity in winter of heating 28° air up to 55°F. Control of the flow of well water in each fan room is automatically regulated from outdoor temperature to give optimum performance at minimum pumping cost.

Next step in the conditioning process is humidification, and for this purpose perforated copper pipes extend into the air plenum, bringing pure steam reduced to two pounds' pressure from copper steam mains running from the Central Plant. Steam is admitted through an automatic regulating valve controlled by a duct humidistat inserted in the air stream leaving the offices and exhausting to outdoors. This part of the system insures that humidity in the building will never fall below 40 per cent, even during the extreme dry spells which occasionally reduce outdoor humidity to levels below 10 per cent.

From the humidifier, the air is drawn into the main supply fan, which then pushes it into a plenum, branching at its further extremity into two separate plenums. At the head of one of these plenums is erected a chilled water heat transfer surface, and at the head of the

other plenum is erected a hot water heat transfer surface, both of these coil banks receiving their water from separate piping systems emanating from the Central Plant. The need for separate piping for hot and cold water is occasioned by the necessity of being able to heat certain parts of the building at the same time as other parts of the building are being cooled. In this fashion, it will be seen that there is created at all times one plenum from which warmed air may be taken, and a second plenum from which cooled air may be taken. Each zone in the building is connected to both these plenums by a duct which travels from each zone through the furred ceilings down a vertical duct shaft and into the fan room, where it branches into a dual connection to the two plenums. A volume damper is installed in each branch and operated by an automatic damper motor which receives its control impulses from a remote thermostat located in the control room of the zone in question. This thermostat positions the two damper motors in such fashion that a proper blend of warmed and cooled air is taken from the two plenums and supplied to the rooms to hold proper room temperature. The action of the thermostat and mixing dampers is completely automatic at all times of the year, and no manual selection switch or change-over thermostat is required to decide whether the cooling or heating function is needed.

Each of the fan rooms has approximately 20 zones of control connected to it. In general, each floor has been zoned separately, and only rooms having the same compass exposure are tied together on a single zone. Corner rooms which have double exposures are always on a zone by themselves, as are interior rooms which have no outside exposures at all, and conference rooms or other quarters where large numbers of people may gather suddenly for study or discussion.

All rooms in each wing have their own exhaust ducts, connecting into a common exhaust trunk beneath the floor extending clear to the basement, where an exhaust blower picks up the vitiated air and blows it through the unexcavated portions of the structure past louvered screens and thus to outdoors. This accomplishes two incidental purposes: first, the forced ventilation of under-floor areas is a strong deterrent to the activities of termites, which might otherwise get into the building timbers; and second, the warm air emerging from the exhaust louvers at ground level helps protect the flowers from early morning frost in winter.

Air-conditioning systems in other buildings differ in detail from that in the Animation Building, but in general adhere to the principle of

completely automatic control with no recirculation of air. There were many special problems for which interesting solutions were devised, but these are of interest mainly to the air-conditioning technician.

This system of mixing damper control, which has been used elsewhere before, but probably never on the scale shown in this building, has worked with excellent success. The building has now been in operation for some nine months, and, considering the conditions of occupancy, widely fluctuating outdoor temperatures, and the large amount of glass area in the building exposed to the sun, there have been strikingly few complaints about atmospheric conditions.

Air handled on the lot by the various air-conditioning units is approximately 40,000,000 cu. ft of air per hour. This is forced through the various duct systems by 135 multi-blade centrifugal fans driven by electric motors totaling 275 hp. The duct systems through which this air is distributed required about 600,000 pounds of galvanized sheet iron and structural iron for their fabrication, and the 250,000 gallons of heated or refrigerated water per hour needed to condition this air is forced through approximately three miles of piping by 18 pumps, totaling 121 motor hp.

The total air-conditioned floor space in the studio comprises about 250,000 sq ft, which is roughly equivalent to a 12-story department store having a 130-foot frontage and 160-foot depth. All told, more than 1300 motor hp are required for all the air-conditioning functions.

#### WELL WATER SYSTEM

Well water is used on the new lot not only for air-conditioning, but also for lawn sprinkling, toilets, and special process uses in the Process Laboratory. Water for these purposes is drawn from two wells, each 300 feet deep, and each provided with a 150-hp submersible pump and motor, sunk to a depth of approximately 80 feet below ground, or 60 feet below the normal water table.

These two pumps tie into a common underground piping system, into which there is connected an elevated surge tank which serves to even out the operation of the pumps. Control of the pumps is regulated from the changing water level in the surge tank, which actuates a controller whose function it is to run one pump or both pumps, depending on the level of the water in the tank.

The amount of water set aside for the precooling function in the air-conditioning plant is 3000 gallons per minute at peak load, representing a cooling capacity of 1000 tons of ice per 24 hours.



## UNDERGROUND UTILITIES

The new studio, consisting as it does of some twenty separate buildings arranged over an area of 51 acres, is in reality a small city, and had to be provided with many of the underground utilities with which modern cities are equipped. Thus, the studio had to construct for itself its own streets, storm drains, sanitary sewer system, sanitary water lines, underground fire-protection piping, fire hydrants, a private telephone exchange, and a complete electric distribution system. In addition, there is underground conduit to accommodate a studio-wide public address system, which is monitored from the telephone office, and a supervisory fire alarm system to give an immediate indication at a central point of the passage of water through any of the main sprinkler valves on the lot. This latter system is not yet completed, but complete provision has been made to accommodate it.

Electric power enters the lot from the lines of the City of Burbank in a 4330-volt feeder which is carried into a main transformer vault through suitable oil-immersed circuit breakers for distribution to the lot. A central switchboard controls the branch feeders which radiate from this central point. Power is distributed around the lot at 4330 volts to three separate transformer vaults located strategically at load center points. In these vaults the voltage is reduced through suitable transformer banks to 440 volts, 3-phase, 60 cycles to provide power for the operation of electric motors, and by means of other transformer banks is converted into 3-wire, 110-220-volt circuits for handling the lighting system. All motors of  $\frac{1}{3}$  hp and larger are operated on 440 volts. The small fractional hp motors are run on 220 volts, single phase.

Should the plant requirements ever exceed the capacity of the present main vault equipment, space has been set aside at the rear of the lot for erection of a studio sub-station capable of taking 33,000-volt service from the City of Burbank and converting it to the studio needs.

In addition to the regular lighting circuits, an emergency lighting circuit has been provided on the lot, servicing certain strategically located lights in corridors, boiler room, and other vital points, this circuit taking its energy from an automatic 25-kw gasoline engine-generator which starts up and reaches full speed within three seconds from the time of power failure.

## GROWING PAINS\*

WALT DISNEY\*\*

In the JOURNAL for December, 1938, there appeared a most interesting paper written by Dr. H. T. Kalmus describing the adventures of Technicolor in Hollywood. I have been asked to prepare an article along similar lines telling of highlights in the history of our company and animated pictures. Messrs. Garity and Ledeen have written a paper for the JOURNAL covering the technical side of our development, so I had better stay on my side of the fence and talk about animation and where I was born and about *Three Little Pigs* and what-about-the-future of the business. When I protested that all this had been written up too many times before, and that such an article would be dull and of little interest to the members of the Society, Mr. Garity said, "That's right!" and left the office with a dirty laugh.

Making this job even more difficult, I found in rereading Dr. Kalmus' paper of 1938, that he had "lifted" semi-philosophic thoughts which I had planned to put in my article. I accuse him of what might be called "prophetic plagiarism," and I resent it, too, because I have so few semi-philosophic thoughts.

For instance, Dr. Kalmus starts off by stating that his developments in Technicolor have been an adventure, and adds the Webster definitions of *adventure*: *chance of danger or loss; the encounter of risks; a bold undertaking; a remarkable experience, a stirring incident; a mercantile or speculative enterprise of hazard*. Now, I had planned to start my paper with this definition and continue with the statement, "My business has been a thrilling adventure, an unending voyage of discovery and exploration in the realms of color, sound, and motion." It has been that! And it has been a lot of fun and a lot of headache. The suspense has been continuous and sometimes awful. In fact, life might seem rather dull without our annual crisis. But after all,

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\* Received Dec. 1, 1940.

\*\* Walt Disney Studios, Burbank, Calif.

it is stress and challenge and necessity that make an artist grow and outdo himself. My men have had plenty of all three to keep them on their toes. But how very fortunate we are, as artists, to have a medium whose potential limits are still far off in the future; a medium of *entertainment* where, theoretically at least, the only limit is the imagination of the artist. As for the past, the only important conclusions that I can draw from it are that the public will pay for quality, and the unseen future will take care of itself if one just keeps growing up a little every day.

The span of twelve years between *Steamboat Willie*, the first *Mickey* with sound, and *Fantasia*, is the bridge between primitive and modern animated pictures. No genius built this bridge. It was built by hard work and enthusiasm, integrity of purpose, a devotion to our medium, confidence in its future, and, above all, by a steady day-by-day growth in which we all simply studied our trade and learned.

I came to Hollywood broke in 1923, and my brother Roy staked me to a couple of hundred. We lived in one room and Roy did the cooking. He was my business manager, and I didn't have any business. His job was to scare up three meals a day, and his job now is to conjure up three million dollars to meet the annual payroll. Both jobs have demanded just about the same amount of sweat, ingenuity, and magic. The main difference is that Roy sweats *more* red ink now. But no matter what the future deals me, I shall consider that I have come a long way, if for no other reason than that Roy doesn't do the cooking any more.

I sold my first animated cartoon for thirty cents a foot. *Pinocchio* and *Fantasia* cost around three hundred dollars a foot. The first *Mickey Mouse* was made by twelve people after hours in a garage. About twelve hundred people are working overtime now in a fifty-one-acre plant with fourteen buildings, four restaurants, its own water system, air-conditioning, and a gentleman named Myron to massage the kinks out of my neck.

My first motion picture camera was "ad libbed" out of spare parts and a drygoods box swiped from an alley off Hollywood Boulevard. It was hand-cranked, the camera. Even then I felt the urge to grow, to expand—I was very ambitious in those days—so we bought a used motor for a dollar to run the camera. It had once been a second-hand motor, but since that time it had seen everything and died. We had to hire a technician to make it go. We have been hiring technicians ever since. Our business has grown with and by technical achieve-



ments. Should this technical progress ever come to a full stop, prepare the funeral oration for our medium. That is how dependent we artists have become on the new tools and refinements which the technicians give us. Sound, Technicolor, the multiplane camera, *Fantasound*, these and a host of other less spectacular contributions have been added to the artist's tools, and have made possible the pictures which are the milestones in our progress.

That first movie camera now stands in all its ad lib splendor in a Los Angeles Museum. Our new multiplane cameras are two stories high and operate by remote control. But, on the whole, the basic tools and technics of my craft had been worked out before I learned the rudiments of animation out of a book in Kansas City.

There had been animated cartoons long before motion pictures. The Stone Age artist came pretty close to animation when he drew several sets of legs on his animals, each set showing a different stage of a single movement. A Frenchman named Plateau was the first to make a cartoon move. In 1831, he invented the *phenakistoscope*, a device of moving disks and peepholes. The successive stages of an action were drawn on one disk. When the disk was spun, the illusion of motion resulted. Many similar devices were invented to make pictures move. The first animated cartoon on motion picture film was made by J. Stuart Blackton in 1906. It showed a fellow blowing smoke in the face of his girl friend. A bit corny, but not bad! *Snow White and the Seven Dwarfs* was not the first feature-length cartoon by twenty years, while the first cartoon mechanically colored dates back to 1919. The greatest single contribution of the pioneers came from Earl Hurd who invented (1915) the idea of tracing the moving parts of a cartoon on celluloids superimposed over opaque backgrounds. This great labor-saving device is still the foundation of our modern method.

The miracle of seeing drawings move was enough to enthrall the early motion picture audiences. Then, as the edge of the miracle wore off, interest in cartoons was revived by numerous series of cartoons built around the antics of stock characters. Some of these series were very popular. Whether or not these pre-Mickey cartoonists ever sat back and thought about the *possibilities* in the medium, I don't know. I was ambitious and wanted to make better pictures, but the length of my foresight is measured by this admission: Even as late as 1930, my ambition was to be able to make cartoons as good as the *Aesop's Fables* series.

I was knocking out a series called *Oswald the Lucky Rabbit* for Universal at the time sound exploded like a bomb under silent pictures. The series was going over. We had built up a little organization. Roy and I each had our own homes and a "flivver." We had money in the bank and security. But we didn't like the looks of the future. The cartoon business didn't seem to be going anywhere except in circles. The pictures were kicked out in a hurry and made to a price. Money was the only object. Cartoons had become the shabby Cinderella of the picture industry. They were thrown in for nothing as a bonus to exhibitors buying features. I resented that. Some of the possibilities in the cartoon medium had begun to dawn on me. And at the same time we saw that the medium was dying. You could feel *rigor mortis* setting in. I could feel it in myself. Yet with more money and time, I felt we could make better pictures and shake ourselves out of the rut. When our distributor, Universal, wouldn't give us the money, we quit. Most of our staff went over to Universal. That hurt! But I had made my Declaration of Independence and traded security for self-respect. An artist who wouldn't is a dead mackerel. Thereafter, we were to make pictures for quality and not for price. The public has been willing to pay for this quality.

Out on my own again, I looked for a new character and hit on Mickey Mouse. The first two *Mickey Mouse* pictures were silent. We couldn't peddle them. It occurred to me that in a world gone sound-mad, since the release of Al Jolson's *The Jazz Singer*, a cartoon with action synchronized to sound would be something of a sensation. My third *Mickey, Steamboat Willie*, was planned with this in mind. By some miracle we managed to figure out the basic method for synchronizing sound and action that we still use. When the picture was half finished, we had a showing with sound. A couple of my boys could read music and one of them could play a mouth organ. We put them in a room where they could not see the screen and arranged to pipe their sound into the room where our wives and friends were going to see the picture. The boys worked from a music and sound-effects score. After several false starts, sound and action got off with the gun. The mouth-organist played the tune, the rest of us in the sound department bammed tin pans and blew slide whistles on the beat. The synchronism was pretty close. The effect on our little audience was nothing less than electric. They responded almost instinctively to this union of sound and motion. I thought they

were kidding me. So they put me in the audience and ran the action again. It was terrible, but it was wonderful! And it was something new!

I took *Steamboat Willie* to New York and started a dreary hunt for a sound company which was not too busy or too expensive to record the sound for me. I finally made a deal with Cinephone. Theirs was a pretty punk sound system until Bill Garity redesigned it later on. But in spite of that, *Steamboat Willie* was an instant hit. It played the Colony, then moved to Roxy's. Mickey was a big shot over night. Lush offers poured in from Hollywood, but Cinephone had us nailed to a contract. A year later, in a joint deal with Columbia, we bought up the contract. Cinephone had given me a bigger picture budget than had Universal, and Columbia had upped the figure considerably again. But soon the increasing quality on which we were building our business demanded bigger and bigger advances. Columbia couldn't take it, so in 1931, we made a deal with United Artists to distribute our cartoons.

This new deal, for all practical purposes, gave us financial independence. Since then, we alone have determined how much our pictures will cost. Not that the industry hasn't had a great deal to say about our picture costs, in one sense. Time and again, it has been said that we were crazy and would go broke. Mack Sennett claimed that we put live-action shorts out of business because they could not afford to spend the money to compete with us. The fact was the reverse. Live-action shorts could not afford *not* to spend more money if it would improve their quality. By 1931, production costs had risen from \$5400 to \$13,500 per cartoon. This was an unheard of and outrageous thing, it seemed. And a year later, when we turned down Carl Laemmle's offer to advance us \$15,000 on each picture, he told me quite frankly that I was headed for bankruptcy. This was not short-sighted on his part. He had no way of seeing what we saw in the future of the medium.

As *Mickey Mouse* became a universal favorite and the money rolled in, we had been able to afford the time and money to analyze our craft. I think it is astounding that we were the first group of animators, so far as I can learn, who ever had the chance to study their own work and correct its errors before it reached the screen. In our little studio on Hyperion Street, every foot of rough animation was projected on the screen for analysis, and every foot was drawn and redrawn until we could say, "This is the best that we can do."



We had become perfectionists, and as nothing is ever perfect in this business, we were continually dissatisfied.

In fact, our studio had become more like a school than a business. As a result, our characters were beginning to act and behave in general like real persons. Because of this we could begin to put real feeling and charm in our characterization. After all, you can't expect charm from animated sticks, and that's about what *Mickey Mouse* was in his first pictures. We were growing as craftsmen, through study, self-criticism, and experiment. In this way, the inherent possibilities in our medium were dug into and brought to light. Each year we could handle a wider range of story material, attempt things we would not have dreamed of tackling the year before. I claim that this is not genius or even remarkable. It is the way men build a sound business of any kind—sweat, intelligence, and love of the job. Viewed in this light of steady, intelligent growth, there is nothing remarkable about the *Three Little Pigs* or even *Fantasia*—they become inevitable.

The *Silly Symphony* series was launched in 1929. In *Mickey Mouse* cartoons, we kidded the modern scene. The material was limited. We wanted a series which would let us go in for more of the fantastic and fabulous and lyric stuff. The *Silly Symphony* didn't give *Mickey* much competition until we added Technicolor in 1932. We thought that color would be worth the heavy extra cost. Color was part of life. A black-and-white print looked as drab alongside *Flowers and Trees*, as a gray day alongside a rainbow. We could do things with color! We could do many things with color that no other medium could do.

I remember Roy coming into the office about this time with a bunch of figures in one hand and eyes full of patient resignation. "How come," began Roy, "How come that last year with thirty men we made thirty pictures, and this year with over a hundred and fifty, you get out only eighteen?" I can't answer that type of question, but the surest way to take Roy's mind off past and present troubles is to tell him that we need a lot more money in the immediate future. Roy has the greatest confidence in me, in our medium and in our future, but he is a business man and doesn't like to live dangerously twelve months out of the year. In this instance, three little pigs and a big, bad wolf were soon to bring him days of peace—not many days, but a few.

*The Three Little Pigs* was released in 1933. It caused no excite-

ment at its Radio City première. In fact, many critics preferred *Noah's Ark* which was released about the same time. I was told that some exhibitors and even United Artists considered *The Pigs* a "cheater" because it had only four characters in it. The picture bounced back to fame from the neighborhood theaters. Possibly more people have seen *The Pigs* than any other picture, long or short, ever made. So you get an insight into the short-subject business when I tell you that *The Pigs* grossed only \$125,000 its first year. *Snow White* grossed over seven million. That's the difference between shorts and features from the profit angle. The low rentals for short subjects has been a chronic headache for us. Our only solution has been to build our prestige through quality to the point where public demand forced the exhibitor to pay more for our product. Theaters paying two or three thousand a week for a feature may pay us only a hundred or a hundred and fifty dollars for a short. Gentlemen, I ask for justice.

Whatever the reason for *The Pigs'* astonishing popularity, it was an important landmark in our growth. It nailed our prestige way up there. It brought us honors and recognition all over the world and turned the attention of young artists and distinguished older artists to our medium as a worthwhile outlet for their talents. We needed these men for future growth, and they came from all over the country to join our staff and be trained in our ways.

The success of the *Three Pigs* was felt throughout our entire business. The income from all our pictures and from merchandising royalties took a sharp up-swing. The magazine *Fortune* declared that our net profit for 1934 was \$600,000 and I'll take their word for it. That's chickenfeed in Hollywood, but we are strictly small fry. We poured the money back into the business in a long-range expansion program pointing at feature-length production and the protection of our new prestige through constantly increasing quality. The *Mickeys* went Technicolor. We enlarged our training school and began a nation-wide advertising campaign for young artists. The production costs on our *Symphonies* shot skyward until some of the little pictures approached the ridiculous figure of \$100,000. But the quality was there, and by 1935 even the *Three Little Pigs* looked dated and a bit shabby in comparison with the newer *Symphonies*. Our staff at this time numbered around three hundred. A greater degree of specialization was setting in. The plant was becoming more like a Ford factory, but our moving parts were more complex than cogs—human

beings, each with his own temperament and values who must be weighed and fitted into his proper place. I think I was learning a great deal about handling men; or perhaps the men were learning how to handle me. But let me tell you this—young artists are just as reasonable and easy to handle as anybody else. Our temperament goes into our job.

We had our technic well in hand. We had learned how to use our tools and how to make our characters act convincingly. We had learned a lot about staging and camera angles. We knew something about timing and tempo. But a good story idea, in our business, is an imponderable thing. It seems to be largely made up of luck and inspiration. It must be exceedingly simple to be told in seven or eight hundred feet. It must, above all, have that elusive quality called *charm*. It must be unsophisticated, universal in its appeal and a lot of other things you can't nail down in words but can only feel intuitively. *The Three Little Pigs*, *The Flying Mouse*, and *The Grasshopper and The Ants*, were examples of good stories. I used to feel at times that there wasn't another good story idea left in the world which could be told in eight hundred feet. The *length* limitation of the *Symphony* became more and more galling. We were batting story ideas around for months and sometimes years trying to get the certain twist, the lacking element, or whatever the idea needed to make it a good story. Our files were filled with abandoned stories on which we had spent thousands. It was inevitable that we should go into feature-length pictures if only for the unlimited new story material this field held for us.

I thought we could make *Snow White* for around \$250,000. At least that's what I told Roy. The figure didn't make sense because we were spending about that much on every three *Symphonies* or 2500 feet of picture. Roy was very brave and manly until the costs passed a million. He wasn't used to figures of over a hundred thousand at that time. The extra cipher threw him. When costs passed the one and one-half million mark, Roy didn't even bat an eye. He couldn't; he was paralyzed. And I didn't feel very full-blooded, either. We considered changing the name of the picture from *Snow White* to *Frankenstein*. I believe that the final figure, including prints, exploitation, etc., was around two million. We sort of half-way explained this to everybody by charging a million of it off to research and development. You know, building toward the future. And this was true, although we hadn't exactly planned it to be that way.



Webster sums up the spirit of the *Snow White* enterprise in his definition of adventure at the beginning of this article—"risk, jeopardy; encountering of hazardous enterprise; a daring feat; a bold undertaking in which the issue hangs on unforeseen events, etc."

As a matter of fact, we were practically forced into the feature field. We not only had to have its new story material, but also we had to have feature profits to justify our continuing expansion, and we sensed that we had gone about as far as we could in the short-subject field without getting ourselves in a rut. We needed this new adventure, this "kick in the pants," to jar loose some new enthusiasm and inspiration.

Research and preliminary work in a small way had begun on *Snow White* as early as 1934. I picked that story because it was well known and I knew we could do something with seven "screwy" dwarfs. Beyond that, we didn't know exactly where we were going, but we were on our way. The picture was released at the turn of the year, 1937-38. At the end of its first year, *Snow White and the Seven Dwarfs* was reported to be the biggest money-maker of all times. It at least settled the question as to whether or not an audience could or would sit through an hour and thirty minutes of animated pictures. Most of the bets were that an audience would go blind. As a matter of fact, that question had been settled as early as 1935, when European audiences lined up in long queues to see a two-hour bill of our shorts. This bill ran for seventeen weeks in Stockholm, and similar all-cartoon bills have been quite successful in this country.

At the time of *Snow White's* release, our staff had grown to about six hundred. Having committed ourselves to a program of both features and shorts, it became necessary again to expand drastically. An additional eight hundred people were added to our payrolls in the next two years. For more studio space, we were forced to lease a row of apartment houses adjoining the studio, and other temporary buildings were erected on the lot. We needed a new studio and in a hurry. Not only did we need more space and more buildings, but the increasing emphasis on the technical side of our craft demanded the most modern and specially designed type of buildings and equipment. The new plant was started in 1939 on fifty-one acres near the Los Angeles River in Burbank. We moved in around the first of 1940.

The two years between *Snow White* and *Pinocchio* were years of confusion, swift expansion, reorganization. Hundreds of young people were being trained and fitted into a machine for the manufacture of

entertainment which had become bewilderingly complex. And this machine had been redesigned almost overnight from one for turning out short subjects into one aimed mainly at increased feature production.

Produced under such conditions and forced to bear its share of this tremendously increased overhead during a two-year period, *Pinocchio* cost something over three million dollars. Suddenly, the world war wiped out half our markets. *Pinocchio* is yet to return its original investment. It has been called a flop. Actually it was the second biggest box-office attraction of the year. *Gone with the Wind* was first. *Pinocchio* might have lacked *Snow White's* heart appeal, but technically and artistically it was superior. It indicated that we had grown considerably as craftsmen as well as having grown big in plant and numbers, a growth that is only important in proportion to the quality it adds to our product in the long run.

The large profits from *Snow White*, short subjects, and the mounting royalties from our merchandising enterprises, had all gone back into the business to pay for the new studio and expansion program. Our payroll had risen to around three million a year. The war had cut our potential picture profits in half. The crisis was on. Another one. It was brought on by what might reasonably be called reckless expenditures. Yet, looking at it our way, it is these expenditures that have put us in shape for the storm. Instead of the one feature-length picture every two years which seemed the limit of our capacity two years ago, we are now reorganized and equipped to release nine features in the next two years, each at a fraction of *Pinocchio's* cost.

The first of these nine features, *Fantasia*, has been released. We have never been so enthusiastic about a picture. Every picture is an adventure, but *Fantasia* has certainly been our most exciting one. We take great music and visualize the stories and pictures which the music suggests to our imaginations. It is like *seeing* a concert. Leopold Stokowski and the Philadelphia Orchestra recorded the music, using a new system of sound recording and three-dimensional reproduction called *Fantasound*. It is our intention to make a new version of *Fantasia* every year. It's pattern is very flexible and fun to work with—not really a concert, not vaudeville or a revue, but a grand mixture of comedy, fantasy, ballet, drama, impressionism, color, sound, and epic fury.

Mickey Mouse and Disney in the same boat with Bach, Beethoven, Stravinsky, and Stokowski! Well, where do we go from there? I

haven't the faintest idea. I have never had the faintest idea where this business would drag me from one year to the next. It's at the controls, not me! But, as I said before, as long as we keep on growing the future will keep opening up. More than any other picture, *Fantasia* shows how much the medium has grown. No doubt, some unimaginative critics will predict that in *Fantasia* the animated medium and my artists have reached their ultimate. The truth is quite to the contrary. *Fantasia* merely makes our other pictures look immature, and suggests for the first time what the future of this medium may well turn out to be. What I see way off there is too nebulous to describe. But it looks big and glittering. That's what I like about this business, the certainty that there is always something bigger and more exciting just around the bend; and the uncertainty of everything else.

Over at our entertainment factory we are training hundreds of brilliant youngsters to carry on the job far beyond where we old timers must leave off. They will train other youngsters. There is no knowing how far steady growth will take the medium, if only the technicians continue to give us new and better tools. For the near future, I can practically promise a third-dimensional effect in our moving characters. Fully exploited, *Fantasound* should prove a startling novelty. The full inspiration and vitality in our animators' pencil drawings will be brought to the screen in a few years through the elimination of the inking process. Then, too, our medium is peculiarly adaptable to television, and I understand that it is already possible to televise in color. Quite an exciting prospect, I should say! And, since *Fantasia*, we have good reason to hope that great composers will write directly for our medium just as they now write for ballet and opera. This is the promise of the next few years. Beyond that is the future which we can not see, today. We, the last of the pioneers and the first of the moderns, will not live to see this future realized. We are happy in the job of building its foundations.



## PIONEERING IN TALKING PICTURES\*

LEE DE FOREST\*\*

To pioneer has always been with me an obsession. Perhaps the yearning to explore new fields was an inheritance from colonial ancestors. Vanished geographical frontiers still left far vaster regions in science and technology to explore. When early wireless began to be a bit crowded the radio telephone field, then scarcely a dream even among communication engineers, beckoned me irresistibly. This primitive beginning of the radio broadcast, in 1908, logically necessitated the development of the electronic amplifier from the audion detector tube (Fig. 1); and thus again I managed to escape the crowd. And when, in 1912, this amplifier proved to be also an oscillator, a boundless ocean disclosing alluring archipelagoes of practical application was opened to scientific research.

It then became apparent that many a forgotten dream of other early inventors might finally be brought to realization. Among such in the sea of television were the scanning disk of Nipkow, the cathode-beam picture of Rossing, Cambell-Swinton's invention of the cathode-scanning beam (recently perfected in Zworykin's "Iconoscope")—all brilliant conceptions which must needs remain only blueprints and Letters Patent, for the simple lack of an inertialess amplifier of a hundred million magnifying power.

Similarly in acoustics the primitive but all-embracing patent of Fritts, breaking all records, embalmed for thirty-six years in the Patent Office; and that of Elias Ries who in 1913, before the photo-electric cell, or the amplifier which could make it useful, described the remaining essentials of photographic sound-on-film recording and reproducing.

In 1919, happily unconscious of these then buried documents, I decided the time had at last arrived when sound photography should definitely give a voice to the picture film.

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\*Requested and recommended for publication by the Historical Committee.

\*\*Hollywood, Calif.

I essayed at first three methods of sound recording, the speaking flame, the tiny incandescent filament, and the glow-tube. The latter soon showed itself to offer the only hope of practical success (Fig. 2).

My first demonstrated actual combination of sound-on-film and talking picture was at my old High Bridge, New York, laboratory in the spring of 1921, shortly before I removed to Berlin. My then assistant, William Garity, still cherishes a few film samples of himself holding the hand microphone, while I served as cameraman.

This early work, when apparently only we two (and he, somewhat skeptically) believed there was a commercial future for the talking picture, evidently sank deep within his soul; for today Garity is chief

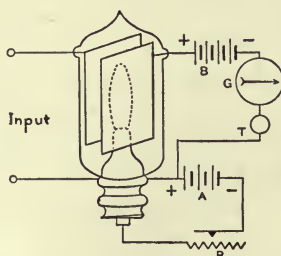


FIG. 1. The De Forest audion—original type.

factotum for Walt Disney; possibly because that primitive recording was chiefly suggestive to him of the squeaks of Mickey Mouse.

It was in the spring of that year, 1921, that my difficulties in developing properly a sadly underexposed sound record and overexposed picture on the same film suggested the use of two separate, synchronized negatives, one for the picture, one for the sound, each given its proper development, and each printed successively on a common positive.

My patent application covering this basic principle was finally rejected after a bitterly contested interference proceeding with that by the Tri-Ergon inventors. The destiny of this latter patent in our Supreme Court is now recent history, familiar to all. I still maintain, however, that here resided a genuine invention, once a total novelty, and now of tremendous practical value.

Shortly after my return to America a year later, in 1922, and my installation in a genuine motion picture studio, that ancient remodelled brewery of Tec-Art on East 48th Street, I was visited by Theodore

Case of Auburn, N. Y. He watched my work and shortly thereafter summoned me to his Laboratory to show me a gassy Western Electric amplifier bulb whose "blue haze" was fluttering in accord with telephone currents from his microphone. Forthwith I sketched out the first oxide-coated cathode glow-tube, which he and E. I. Sponable, his gifted assistant, constructed and named the "AEO light" (Dec., 1922); whereupon I proceeded to scrap my radio-frequency recording oscillator and metal-cathode glow-tubes in favor of this low-voltage

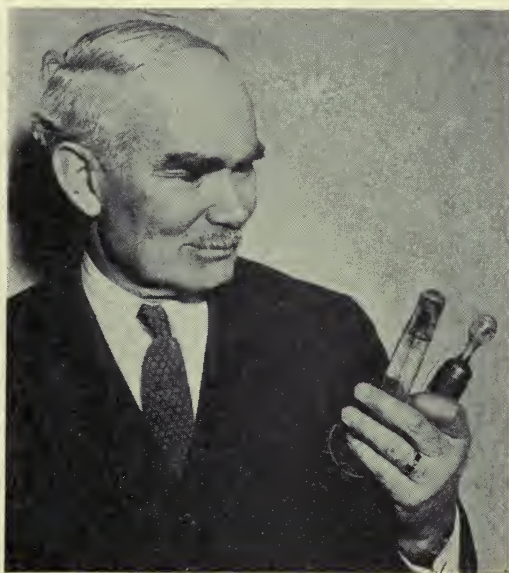


FIG. 2. Lee de Forest with two early types of glow-tubes for sound-on-film recording (1925).

direct-current source. I also discarded my Kuntz photoelectric cells, difficult to obtain with uniform quality, in favor of the Case far more sensitive "Thalafide" (resistance) cell, enthusiastically regardless of the fact that the latter cut off quite effectively below 3000 cycles.

After this experience I returned to the use of the photoelectric cell with resultant gain in quality, and to the use of the metal cathode recording light, but designed to operate on low voltages, thus obviating the use of the radio-frequency oscillator of my first system. I shall refer to this feature hereafter.



But now the more directly commercial requirements, following upon my introduction of the "Phonofilm" to Broadway audiences

# THE RIVOLI

BROADWAY AT 49th STREET NEW YORK CITY

Operated in conjunction with THE RIALTO, Times Square

HUGO RIESENFELD, DIRECTOR

**FIRE NOTICE**—Look around NOW and choose the nearest exit to your seat. In case of fire walk (not run) to THAT EXIT. Do not try to beat your neighbor to the street.

THOMAS J. DRENNAN, Fire Commissioner.

PROGRAM CHANGED EVERY SUNDAY

PRICES		EVENINGS		MATINEES	
Evening prices prevail at Satur- day, Sunday and Holiday Matinees	Orchestra	85 cents	Admission	77 cents	
			War Tax	8 cents	
	Balcony	50 cents	Admission	45 cents	
			War Tax	5 cents	
	Orchestra	50 cents	Admission	45 cents	
			War Tax	5 cents	
Balcony	30 cents	Admission	27 cents		
		War Tax	8 cents		
LOGES		Always	90 cents	Admission	90 cents
			War Tax	9 cents	

The Rivoli opens at noon daily, performances begin at 12 noon, 2:15\*, 4:15, 7:30\* and 9:30 p. m. Sunday first performance starts at 1. Asterisks indicate full presentation with orchestra, soloists and scenic effects. J. Van Cleft Cooper and Frank Stewart Adams at the organ.

## PROGRAM

Week of April 15th, 1923

### RIVOLI ORCHESTRA

FREDERICK STAHLBERG, Conductor WILLIE STAHL, Asst. Conductor

## 1. OVERTURE

"ORPHEUS IN THE LOWER WORLD"

Jacques Offenbach

FREDERICK STAHLBERG and WILLIE STAHL conducting

Although Orpheus is not mentioned in the Homeric poems, the story of his attempting to bring back his dead wife, Eurydice, from the lower regions was a favorite of the Greeks and has been ever since. It was a subject of the first grand opera ever written, by Peri in 1600, and is the theme of Gluck's most famous opera, produced in 1762. Offenbach's burlesque of the old myth was produced in Paris in 1858, and its jolly tune made it a great success. The overture is one of the finest specimens of light music.

## 2. THE PHONOFILM

*The Phonofilm is the latest invention of Dr. Lee de Forest and is a long stride forward in the development of the talking pictures. For the first time it has been made possible to record the picture and the voice or music on the same film, thus insuring perfect synchronization. This is the first public showing.*

FIG. 3. Section of Rivoli Theater (N. Y.) program for the week of April, 15, 1923, announcing de Forest phonofilm demonstration.

under the far-visioned sponsorship of Dr. Riesenfeld, at the Rivoli and Rialto Theaters on April 15, 1923 (Figs. 3 and 4) resulted in filing early patent applications in 1923-25 on such extremely practical

inventions as these: the use of two or more picture cameras at different angles and focal distances, all synchronized to a common sound-recording camera; the blacking out by printing, of the otherwise noisy pauses in the positive sound-track (the basic patent in all processes of "noiseless recording"); the method of dubbing sound recorded in synchronism with a projected picture (Fig. 5). This was practiced first in 1924 for *The Covered Wagon*, as exhibited in the Rivoli Theater during portions of the "Supper Shows" when Riesenfeld's Orchestra was not playing. We did the same in 1925 for his splendid

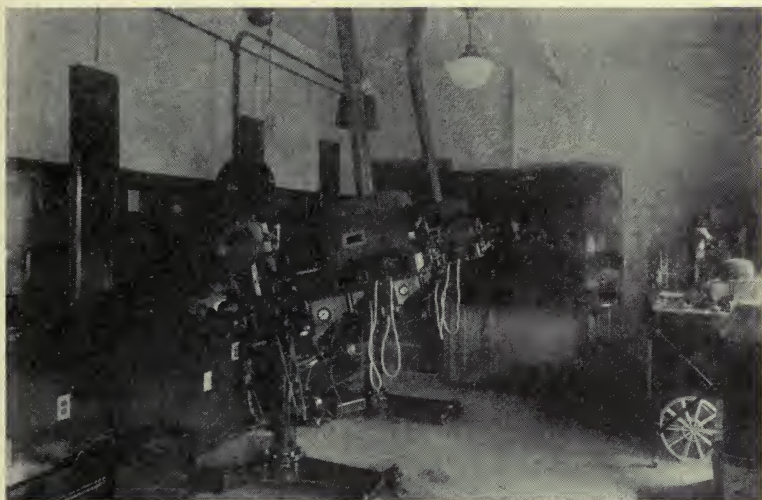


FIG. 4. Rivoli (New York) Theater projection room, Phonofilm equipped (1923).

score of *Siegfried*, actually recorded in the Century Theater while the orchestra was playing to the projected picture.

Monologue numbers by Eddie Cantor, George Jessel, DeWolf Hopper and Chic Sale; dialogs between Gloria Swanson and Thomas Meighan, and Weber and Fields; Fokina's Swan Dance; playlets with Raymond Hitchcock; orchestra recordings by Ben Bernie, Paul Specht, Otto Wolf Kahn, and similar entertainment made up our repertoire during this early period of 1923-27 (Fig. 6).

It may not be remembered that Technicolor was first wedded to sound in the spring of 1925, when Balieff's entire *Chauve Souris* was thus recorded, using a sound-camera synchronized to the color camera,

whose noise was quite successfully suppressed beneath a quilt blimp within an "ice-box" booth with walls eight inches thick. The sound-track was then printed on the green positive, which dyed surface, although serving better than the red, was found quite unsuitable.

Nevertheless certain numbers of this production were exhibited during 1924-25 to enthusiastic audiences in the London Tivoli, and in Japan and Australia.

About this same time I adopted as standard back-screen equipment large vertical exponential horns of wood with a cone-speaker at the

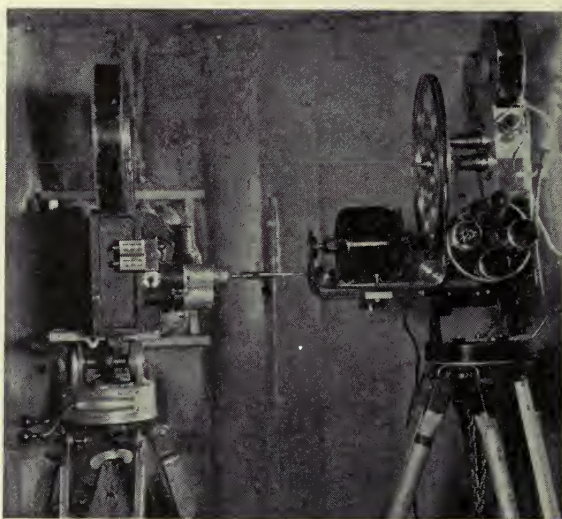


FIG. 5. De Forest sound-on-separate film cameras (1924).

base, and trumpets with Western Electric dynamic receivers located in the bell of the horn. Theater screens were yet unperforated.

Another very practical patent taken out during this era covers the camera "blimp," in an acoustically treated studio.

"Phonofilm" reproducing apparatus installed in thirty-four theaters scattered throughout the East in 1924-25 led to the joint invention by Louis Reynolds and the author of the now well known "tone-control," whereby the operator, or a monitor in the auditorium itself, was enabled to mix the relative values of high and low frequencies to suit best the acoustic characteristics of the theater, or as the audience grew or diminished.



My early theatrical experiences were replete with humorous incidents, interspersed with discouragement and heart-failure. For example, the only occasion on record when one of my first operators, Billy Brinkman, failed to forget to turn on the amplifier switch before he was applauded or kicked into that action was when he went home after the show one night and forgot to switch the amplifier off! The following matinee went off without a hitch. Unquestionably I shortened my life by several years by dashing up long flights of gallery stairs, two at a stride, to endeavor to start or improve the sound reproduction.



FIG. 6. Entrance to Capitol Theatre, New York (1927).

The spring of 1924 witnessed the first talking Newsreel, when an improvised sound-truck journeyed to Washington to record a pre-campaign talking-picture of President Coolidge on the White House lawn. That same summer saw also the Progressive Candidate, Senator La Follette, and the Democratic, John W. Davis, vieing for motion picture theater audience popularity. In 1925 Al Smith and "T. R., Jr.," each visited my studio to tell the recording camera why he should be elected Governor of New York.

The early public acceptance of this type of News Weekly readily convinced Manny Cohen, of Pathé News, that it possessed an assured future. Only our exceedingly modest royalty demands prevented

him from thereby saving millions in later royalties for that organization.

Today, when the entire motion picture world has been for several years almost 100 per cent "talkie," it seems to me incredible that only a little more than a decade ago not one of the "Big Guns" in the industry believed that the talking picture had any place in the theater. Such "best minds" as Adolf Zukor, Sidney Kent, Goldstein, *et al.*, turned a deaf ear to all arguments by myself, Hugo Riesenfeld, and Harold Franklin. When I found that William Fox was a fellow passenger on the *Berengaria* as I returned with my demonstration equipment from the Berlin Laboratory, he refused to meet me even to discuss the subject. And when in 1924 he returned to New York and learned that Phonofilm was actually installed in some six of the Fox houses he peremptorily ordered them all taken out, without even deigning to witness a demonstration.

Yet a year or so later, when the far-sighted Courtland Smith had, almost surreptitiously, installed the Case equipment in the Tenth Avenue studio, Fox, then very likely aroused by reports of how "Vitaphone would astonish the world," lost no more time in tying up with the invention and launched a program which brought into being an eight million dollar "Movietone City."

Even Sam Katz, astute purveyor of the newest and most daringly original acts and stunts for entertaining a blasé public, turned in 1926 the glazing eye and the clammy hand to my lieutenants who sought a limited-term contract to road-show this "short-lived novelty" of the "Talking Picture."

Unquestionably it was the absolutely unique prescience and courage of Sam Warner, and later his brothers, which finally resulted in arousing the motion picture industry to the belated realization that here at last science and invention had created a new instrumentality, one which the mute public had long and patiently awaited; and which, once launched on the sea of public acceptance, was destined to sweep over those antiquated studios and half-empty theaters with a tidal wave of irresistible momentum, ruthlessly scrapping their worn-out equipment, outdating their time-honored technic, relegating their priceless art and high-priced artists to an oft-lamented limbo, at a cost in millions which staggered even the intoxicated imagination of Wall Street, in the millennium of predepression "rugged individualism."

But although Vitaphone and phonograph-recording got away first in its race with film-recording, the terrific handicaps of its involved

technic, geometrically increasing as its public acceptance grew, inevitably led to its general abandonment in favor of the numerous practical advantages which I regarded at the very commencement of my researches as inherent to any photographic sound-on-film process.

And while on the subject of future developments I venture to prophesy an independent volume-control sound-track, shown in an early patent, will, I believe, yet demonstrate its utility in the art. The second track offers certain advantages in dubbing, avoiding all photographic complications of superimposing a loud record upon a weaker, or the reverse. In general, the inherent limitations of the emulsion may be entirely eliminated by the use of the double sound-track.

Although the author has been for the past five years quite outside of the then too crowded talking-picture activities, yet to look back upon all this history of invention, this genuine social revolution, this Caesarian birth of a national industry, in which it was his fortune to pioneer—is to me now at least a source of grim satisfaction, impossible to express.



## TWENTIETH CENTURY CAMERA AND ACCESSORIES\*

D. B. CLARK AND G. LAUBE\*\*

*Summary.*—Although the new Twentieth Century camera was designed primarily to reduce noise, it also embodies many of those conveniences and devices which spell speed and aid in cost cutting.

The camera has been designed and built along new principles and, instead of trying to hold the noise in the camera case or the blimp, the noise has been reduced at its source. The fast-moving reciprocating parts are as light and as small as possible, and when assembled yield uniform acceleration and deceleration, with a resultant optimum movement of the film and a reduction in noise-making vibration. This, when coupled with a patented sound-insulating mount for the film-moving mechanism, reduces the noise output to a level substantially equivalent to the noise level of the best blimped camera available. Other features included in the camera are described in the paper.

Although the Twentieth Century-Fox Film camera has been designed primarily with the idea of reducing noise so that it may be used without a blimp, it also embodies many new devices and accessories which make for speed and ease of operation. It may properly be called a Cameraman's Camera, since it was built by cameramen for cameramen. The authors, together with Robert Stevens and the late Charles Miller, who conceived and designed this camera, at the outset realized that there were two ways of reducing noise: one was to insulate against noise transmission by using a camera blimp—the old way; and the other, or modern way, to reduce the noise at its source. They rejected the prevalent idea that noise could not be further reduced at its source, and set about developing a silenced camera along entirely new lines. The theory was that if all moving parts, particularly reciprocating parts, were made as small and as light as possible, and were then moved with uniform acceleration and deceleration, not only would the minimum amount of vibration be set up, thus reducing the noise at its source, but an optimum movement of the film would also result. In this

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\* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received September 30, 1940.

\*\* Twentieth Century-Fox Film Corp., Hollywood, Calif.

## TWENTIETH CENTURY CAMERA

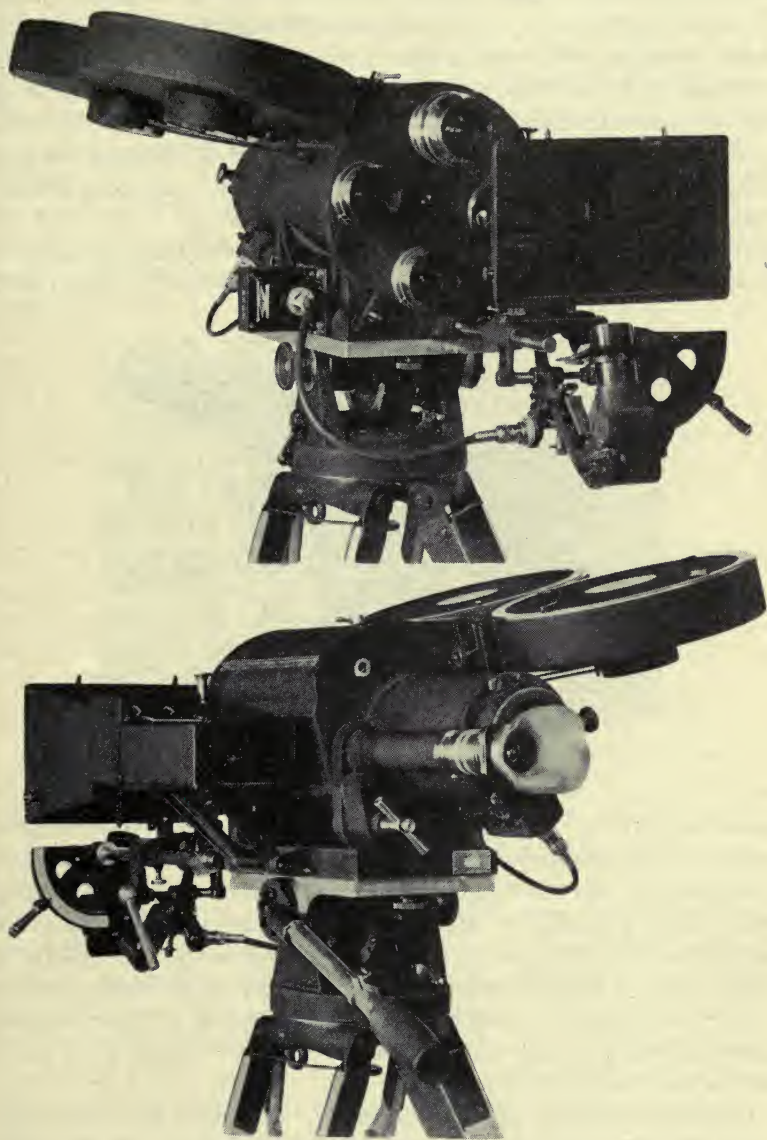


FIG. 1. Two views of the new camera.

camera this theory is utilized to the full extent with amazing results. However, it was realized that a certain amount of vibration would be set up regardless of construction, and a way was sought to eliminate even this. The result was a sound-insulating mount for the film-moving mechanism, designed to absorb certain of the vibrations and to convert other vibrations into inaudible frequencies. This mount incorporated in this camera plays a part in reducing the final noise output to a level less than the noise level of the best blimped camera available today.

While the design was directed primarily toward noise-reduction, there are also embodied in the camera other features dealing with

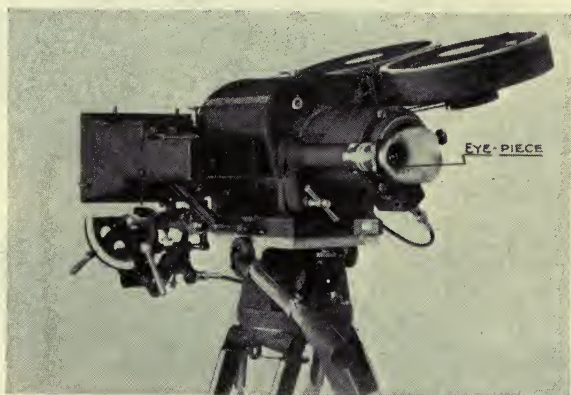


FIG. 2. Focusing position.

improvements in photographic characteristics and conveniences, such as a new focusing device, novel lens mounts, follow-focus monitoring finder, improved shutter, new type of film-moving mechanism, synchronizing means for background projection shots, sound-proof-magazines with film spool lock, hydraulic free-head, lens calibrating system, and a slating device, all tending to produce speed and accuracy in operation. One of the most important of these features comprises the focusing means, which is particularly pleasing to directors and cameramen.

Instead of sliding the case laterally, as cameramen are accustomed to do now for lining up and focusing, the case, with the magazine, is rotated about the shutter axis. To do this, the case is mounted in a yoke and when the magazine on the case is in an upright posi-



tion, the camera is in a shooting position (Fig. 2). For focusing, the case is tilted 75 degrees about the shutter axis, which removes the film-moving mechanism and the film-loop away from the photographing aperture and brings a ground-glass and an aligned optical system into position behind the aperture. Under this arrangement, focusing is done directly through the photographing lens by means of an eyepiece mounted on the rear of the yoke and the optical system through the case. The operation is simple, fast, and accurate, and the magazine in the inclined position is out of the way, which gives a decided advantage for lining up shots. A small handle is mounted on the rear of the yoke for rotating the case into and out of shooting position.

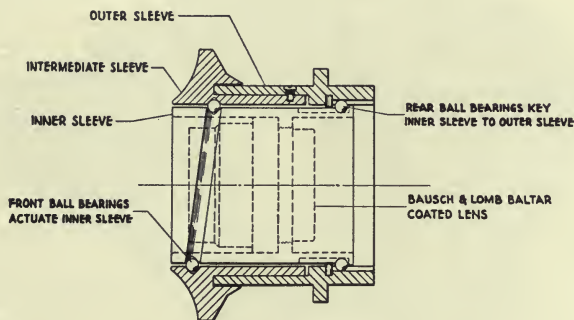


FIG. 3. Lens mount.

Next is the lens mount, which is built up of three concentric sleeves: an outer sleeve, an inner sleeve, and an intermediate sleeve, and comprises front and rear ball-bearings to support and align the sleeves (Fig. 3). The outer sleeve acts as a support and is adapted to be attached to the lens turret of a camera; the inner sleeve is the lens barrel, and the intermediate sleeve rotates between the other two sleeves. The inner sleeve or the lens barrel is splined to the outer sleeve to prevent its rotation with the intermediate sleeve and the rotary movement of the intermediate sleeve is translated into rectilinear movement of the lens barrel by means of the front ball-bearing running in helical grooves on the inner and intermediate sleeves. The amount of lens movement therefore depends upon the pitch of the helical grooves, and the pitch is calculated and constructed to yield the proper rectilinear focusing movement for lenses of various focal lengths with the same amount of turning of the intermediate

sleeve in all cases. The result is that the focusing segment may be standardized for lenses of all focal lengths, since the same amount of turning movement is required for focusing all lenses. This movement, being the same for lenses of all focal lengths, is utilized for focusing and training a follow-focus monitoring finder (Fig. 4).

This finder is operated from the side of the camera in the conventional manner and is hinged so that it may be swung into an out-of-the-way position for opening the camera case. In order to avoid the usual parallax, due to the separation of the finder optical system from

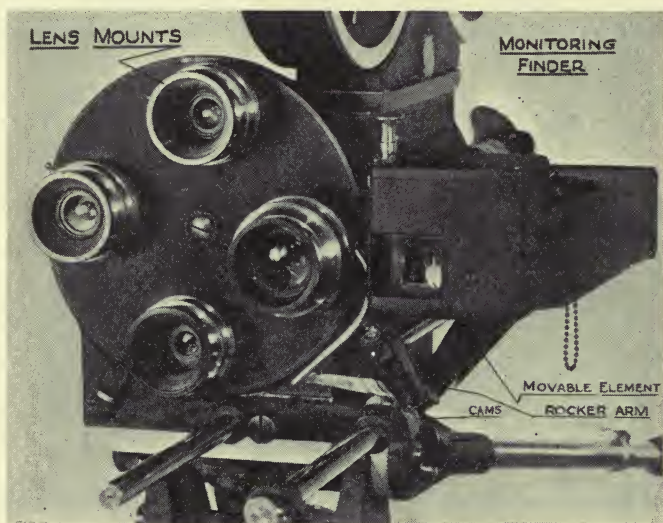


FIG. 4. View showing monitoring finders.

the camera lens, the finder is equipped with a means for moving the finder lens in a diagonal path, so that as the lens is focused its optical center is also offset to compensate for the parallax between the monitoring system and the camera system. Both the camera lens and the monitoring finder are controlled through the conventional focusing arm on the camera, which not only properly focuses the camera lens through the regular focusing link but also focuses the monitoring finder lens, and at the same time trains the monitoring lens upon the same field as the camera lens by means of a cam and rocker-arm arrangement, which moves the movable element of the finder in a diagonal path. For lenses of different focal lengths, differently

shaped cams are used, some of which are seen in Fig. 4. This insures that the cameraman will have the same boundaries of the field in the monitor as are seen by the camera, regardless of field distance or the focal length of the lens. Provision is made for optionally and rapidly throwing the monitoring lens back to its original position on infinity for a quick reference cut back to the background field of the camera lens.

In keeping with the noise-reduction purposes of the camera, careful attention has been given to the shutter. In order to avoid focal-plane disturbances due to vibrating air columns, the shutter has been formed of very thin material and has been streamlined wherever possible. The shutter opening has been made variable and can be used from 45 to 200 degrees and still fall within the dwell period of the film movement. In designing the shutter and the aperture, it was found that the position of the aperture with respect to the axis of the shutter was an important factor. By enlarging the shutter and placing the aperture as far from the shutter axis as possible, the opening and closing time of the shutter was considerably reduced. In Fig. 5 the location of the Twentieth Century aperture is shown.

Due to the wide shutter, its opening and closing time is considerably less than half that of the average motion picture camera. This feature provides a longer dwell period for the film, which enters largely into the photographic improvements of the camera and requires a faster type of film-moving mechanism.

The film-moving mechanism (Fig. 6) embodies some new principles and new design. The chief objective in designing the movement was, first, to provide the fast film movement required, and at the same time hold the movement of the reciprocating parts to a uniformly accelerating and decelerating motion. Other considerations were to make the moving parts, particularly the reciprocating parts, as light as possible and to provide a construction wherein the bearing surfaces would be rounded surfaces of considerable extent with no line contact bearings. To meet these conditions, the pivoted arm

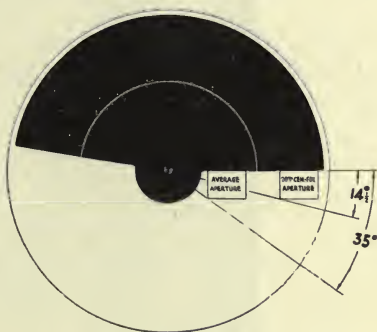


Fig. 5. Diagram of enlarged shutter, with aperture placed farther from the axis.



was adopted with a sliding sleeve worked from an eccentric pin. This structure not only provided the proper bearing surfaces but lent itself admirably to the requirements of the take-down movement. The take-down pin itself is a very small cam-actuated member slidably mounted in the swinging end of the arm (Fig. 7). By properly designing the cam movement for the take-down pin and correlating this movement with the eccentric movement controlling the pivoted arm, the take-down pin may be made to trace a path as shown in Fig. 7.

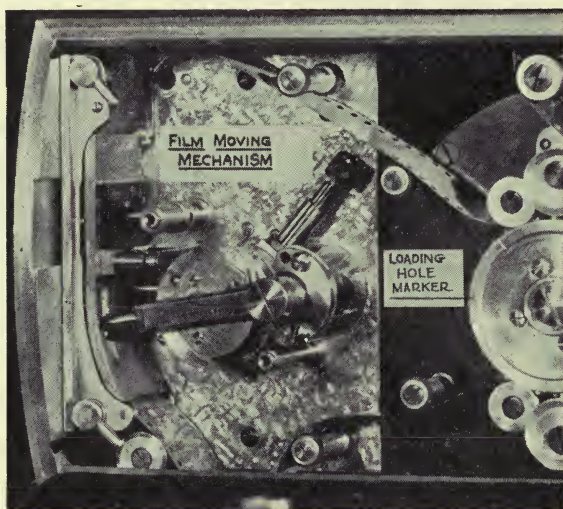


FIG. 6. Film-moving mechanism.

Here it will be noted that at the points where the pin actually enters and leaves the sprocket-holes, the movement of the pin is substantially perpendicular to the film. These two movements occur at the time when the take-down arm is substantially at rest. Since the film is at rest there is no focal-plane disturbance of the film by the sawing action of the pin in entering or withdrawing from the sprocket-hole.

The speed of the take-down pin arm has also been carefully designed and calculated, and is best shown in Fig. 8. This curve of the speed of the take-down pin with respect to time shows that the movement approaches a sinusoidal curve, which is the ideal condition.

The curve has a smooth contour and displays no irregularities which would denote sudden changes in speed, indicating disturbances that would set up audible vibrations. This is brought about by the sliding sleeve and eccentric pin, in combination with the pivoted arm,

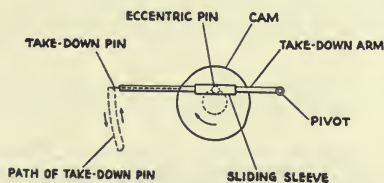


FIG. 7. Schematic arrangement of movement.

which produces the uniformly accelerated and decelerated movement of the take-down pin that not only reduces shock and vibration but yields the optimum movement to the film. It might also be pointed out that the highest speed of the Twentieth Century camera pin movement is under seventy-three inches a second.

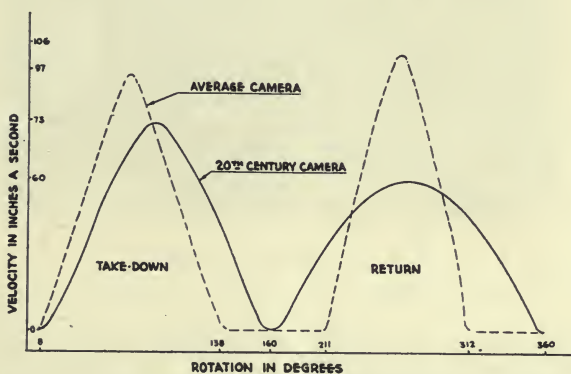


FIG. 8. Velocities of intermittent movements at take-down pins.

In conjunction with the take-down pin are employed two register pins which engage the film on opposite sides directly below the aperture (see Fig. 6). The movement of these register pins has been so designed that the pins hold the film in position until the take-down pin has engaged the film, whereupon they release and pass control of the film to the take-down pin. This correlation of pins has the film under control at all times and insures that there can be no movement

of the film after the shutter once starts opening. The register pins are operated from a scroll-cam properly designed and correlated with the eccentric and the cam that operates the take-down pin to insure this movement. Attention is called to the convenient loading pins and the loading hole marker. Convenient means is also provided for holding the register pins out of engagement for loading purposes.

When shooting background projection shots, the cameraman is often worried over the synchronism of the shutters, and whether he is getting the full amount of light possible. This camera provides

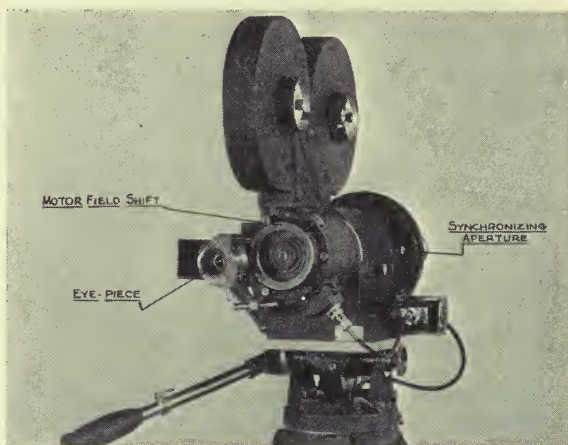


FIG. 9. Shooting position.

a very simple means for checking the position of the camera shutter, with respect to the projector shutter by a little synchronizing aperture (Fig. 9) which is 180 degrees removed from the photographing aperture and is positioned within the radius of the shutter. Therefore, when the cameraman looks through this aperture and sees light on the background projection screen, he knows that the camera shutter is substantially 180 degrees out of phase with the projector shutter. It is then merely a matter of adjusting the phase relation of the shutters until this aperture goes dark. The darkest point would indicate the point where the shutters are in correct phase relation.



In conjunction with the synchronizing aperture, the camera carries means for rotating the motor field so as to bring the camera shutter into the proper phase relation with the projector. For this purpose there is a motor field shift ring on the rear of the motor housing, which is arranged through a specially designed structure to rotate the motor field. To line up a process shot, it is merely a matter of standing behind the camera, peering through the synchronizing aperture and turning the motor field shift ring on the back of the motor until the synchronizing aperture goes dark, whereupon the

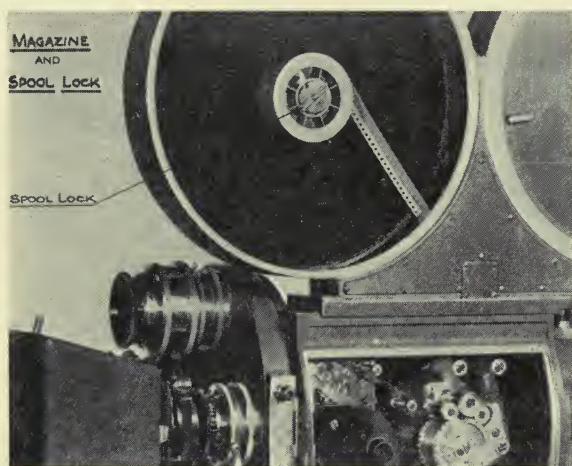


FIG. 10. The magazines are insulated to reduce noise.

cameraman knows that the two shutters are in synchronous relation. A thumb-nut locks the field in position.

As a means toward the end of reducing noise, the magazines were specially treated with interior and exterior insulation (Fig. 10). In addition to these precautions, an anti-rattle film spool spindle was designed. This spindle clamps the film spool firmly and not only prevents the spool from rattling, but by eliminating wobbly movement of the spool tends to force the film to pile up in smooth reels, thus preventing any side scraping.

Having built a camera that was believed would meet the stringent requirements of directors of photography, the inventors and engineers set about to design a worthy accessory in the form of a new free-head.

In keeping with the novelty of the camera, they discarded the old idea of frictional free-heads and conceived and designed a free-head (Fig. 11) wherein no friction is employed for resisting either the tilting or the panning movement. Both these movements are made against a precisely controlled hydraulic resistance. The hydraulic resistance used in these movements provides a silky, smooth drag having no jerkiness due to friction suddenly letting loose, or unevenness due to uneven wearing of the friction plates, no matter how big the swing or how fast or slow the movement. There is a distinct difference in the feel of this movement over the frictional movement,

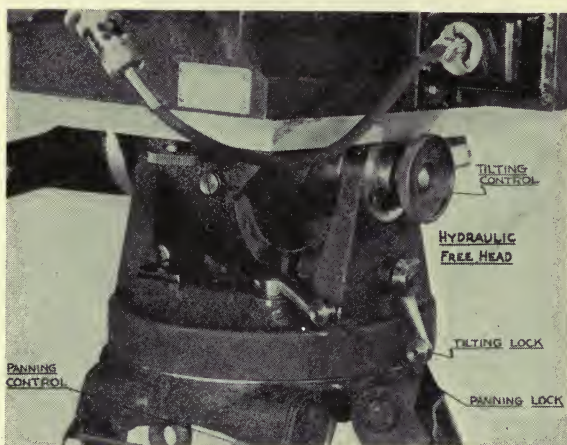


FIG. 11. Close-up of free-head.

which can not be appreciated until once it has been experienced. The tilting control is on the side of the free-head yoke and the panning control is directly beneath the free-head in the apex of the tripod. Both movements are locked by the convenient lever nuts shown in the photograph.

In order further to smooth the path of the cameraman and make the practical use of photoelectric meters possible, the old method of calibrating the light stops on lenses was discarded and a new and revolutionary method inaugurated. This new method is based upon the proposition that the only true way of rating the light-transmitting capacity of any lens is by measuring the actual amount of effective light transmitted through the lens. The old method, whereby lenses

were rated with respect to light speed by the ratio of the aperture opening to the focal length, did not take into consideration the human error in measuring the aperture, the number of elements in the lens, the arrangement of the elements, the different compositions of the glass, or the light lost by reflection and absorption. All these physical characteristics enter into the light-transmission capacity of any lens. Consequently, under the  $f$ /system, lenses of different makes and different focal lengths would not transmit the same amount of light under the same light stop. This fact became more and more evident as lenses of different makes and different focal lengths were interchanged in a procession of shots during a day's shooting, and the cameraman found it becoming more and more difficult to match negative densities in his day's shooting. Under the supervision of D. B. Clark, one of the authors, all Twentieth Cen-

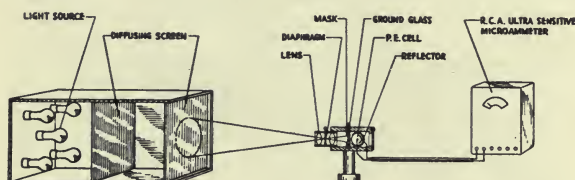


FIG. 12. Illustrating method of calibrating lenses.

tury lenses have been calibrated with respect to light transmission and rated according to the actual amount of effective light transmitted. The ratings of the different apertures are all referred to a standard light base, which has been established and maintained for lens calibration. The means for doing this is schematically shown in Fig. 12, and comprises a source of light which is diffused and maintained at a fixed level and a lens holder arranged to be placed closely in front of the source of light. In the lens holder there is another screen, preferably a ground-glass, which receives the focal image of the lens, and back of this screen is a photoresponsive tube of the voltaic type. The output of the tube is connected to an ultrasensitive meter. The whole system is standardized by measuring the light transmitted through a carefully selected reference lens set at the conventional  $f/3.2$ . The meter reading for this setting is used as the standard reference level for all lenses and the system is calibrated from this reference lens and checked against this lens during



the calibration of other lenses, thus minimizing errors from fluctuations in the light-source or the output of the photoelectric cell.

In calibrating a lens, the lens is mounted in the holder. The diaphragm control is then operated until the meter reads the same level as it did on the standard setting. This would be the  $f/3.2$  reading on this lens, and light stops in both directions away from this point may be made and calibrated on the lens by multiples of the current shown on the meter. It will be noted that the lens holder may be moved with respect to the light-source, the only requirement being that the field subtended by the lens does not exceed the uniformly

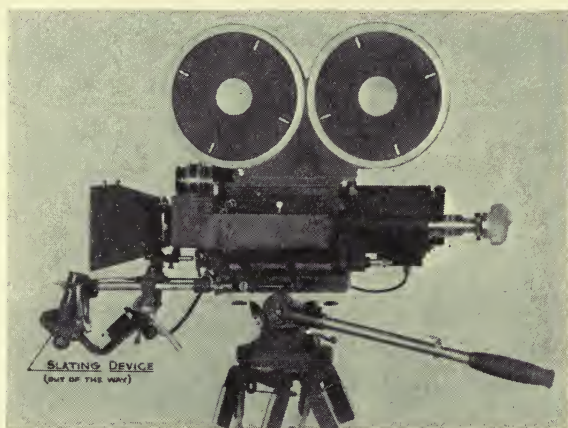


FIG. 13. Shooting position of slater.

lighted field source. The equipment shown in Fig. 12 may be used in daylight upon a bench in a laboratory and will yield sufficiently accurate results to calibrate a lens system under this new method whereby photographic results may be mechanically improved and negative densities may be more perfectly matched. The success of this system is evidenced by the uniform results obtained by all cameramen who have worked with lenses so calibrated. Particular success has been had on exteriors where light stops are numerous, and even more so when working with coated lenses which have a high light transmission characteristic, regardless of the make or design of the lens.

Probably one of the most useful camera accessories developed in recent years is a little semi-automatic slating device (Fig. 13), de-

veloped by D. B. Clark and colleagues at Twentieth Century-Fox Studio. This little device is a complete unit in itself and carries its own optical system, its own illumination, and means for mounting the indicia required to slate the film. In the photograph showing the camera shooting position, it will be noted that the device is suspended on the matte box bracket, and when not in use hangs inconspicu-

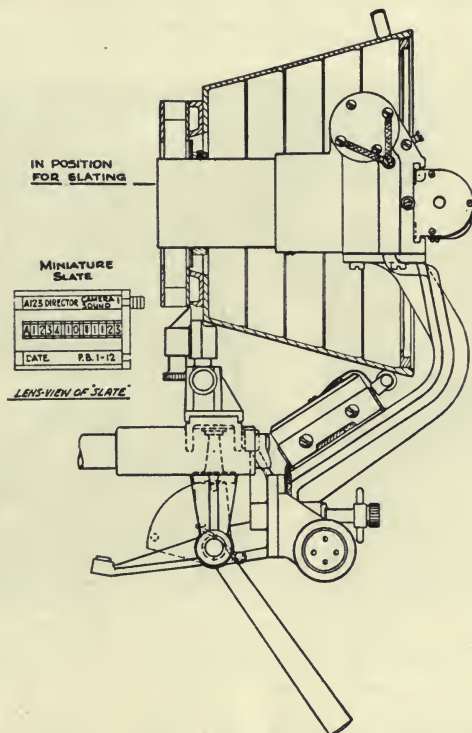


FIG. 14. Slating device.

ously below the sunshade. From this position it is merely a twist of the wrist to throw the slating device upward and around into the sunshade a few inches in front of the camera lens before the camera starts turning (Fig. 14), and, since the device is arranged to block off all foreign light from the camera lens and automatically supply its own illumination, the first frame of the slate on the film can be used as a cue mark. Furthermore, the slate is exposed while the camera is coming up to speed, with no interference of the actors on the set.

This method saves considerable time as well as the film ordinarily wasted in bringing the camera up to speed, and does away with the disconcerting practice of a slate boy or camera assistant thrusting a slate in the faces of the players after they are all set for action.

The miniature slate is easily removed and numbers are quickly changed with a pick provided, or any pointed instrument (Fig. 15). Space is provided for the names of the director, cameraman, and sound man, production number, camera number, date, scene, take

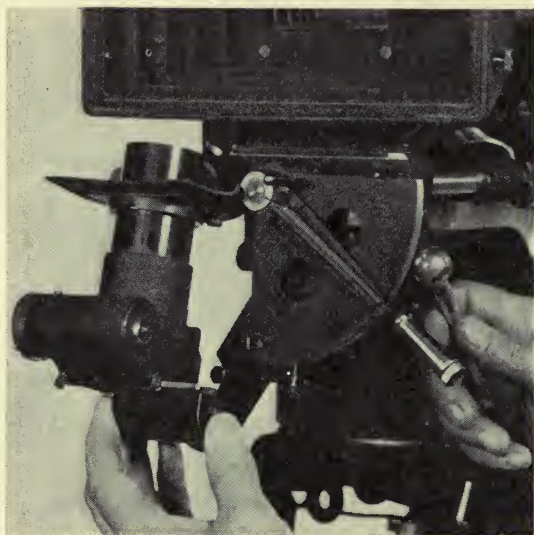


FIG. 15. Removing miniature slater from slating device.

number, sound-track, playback, and start. These, of course, can be varied to meet requirements. The indicia are placed on a plane surface, including the number faces, which provides a flat reflecting surface for projecting them through the optical system on to the film.

Although this camera has been designed primarily to reduce noise, nevertheless the authors believe that, together with the accessories, it eliminates many inconveniences and annoyances that the cameramen have so long encountered, and places in their hands a device which offers the maximum in economy and efficiency, as well as paving the way for a greater margin of excellency in photographic quality.



## PROBLEMS IN TELEVISION IMAGE RESOLUTION\*

C. FREDERICK WOLCOTT\*\*

*Summary.*—This paper discusses some of the problems involved in the consideration of suitable standards now before the National Television Systems Committee. Resolution is approached from a standpoint of the number of lines and fields within the limits of presently assigned channels. Related problems touched upon are flicker frequency vs. illumination, and some of the difficulties which must be guarded against with colored images such as rainbow effects and flicker, both of which can be minimized by using relatively high frame frequencies. The effects of motion, which tend to smear detail, are discussed in relation to frame and field frequency.

The major limitations of present scanning spot shape and intensity distribution, which determine the vertical and horizontal widths of confusion, have been removed in the laboratory, introducing the possibility of markedly improved definition with a given number of lines and fields, which must be reckoned with in determining standards.

The purpose of this paper is to create a deeper appreciation of some of the problems in television which need to be settled by mutual agreement within the industry before we can expect commercialization, which, in turn, will inevitably be followed by an expansion to a national service of a medium which has much to offer the American public. In the space allotted for this discussion of image resolution only the primary factors can receive any attention.

We will make the broad assumption that, regardless of the number of frames, fields, or lines and element areas, items such as the following are roughly equivalent for the various systems discussed:

- (1) Contrast range (roughly equivalent to gamma).
- (2) Visual response and resolution as a function of brightness.
- (3) Overall phase delay linear.
- (4) Amplitude response and band width.
- (5) Shading.
- (6) Screen color.
- (7) Spot shape distortion.
- (8) Thermal noise.

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\* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received October 25, 1940.

\*\* Gilfillan Bros. Inc., Los Angeles, Calif.

- (9) Reflection and refraction (caused by glass envelopes).
- (10) Optical systems.

Image resolution will be discussed in its broader sense, necessarily including frame, flicker, and line frequencies which, because of the scanning methods used, are some of the direct determinants of resolution within a given transmission band width.

The industry and the Federal Communications Commission are unanimous in accepting a 6-megacycle channel as the maximum desirable for the transmission of

a single public television service within the presently useful portion of the radio frequency spectrum.\* Let us, therefore, use this as a basis for consideration of other factors.

Fig. 1 shows the manner in which such a channel is at present utilized. Part *A* is the emission characteristic of the transmitters, and part *B* is the overall response characteristic for sight and sound sides, in the receiver. Sound transmission and reception, accomplished at the high-frequency end of the channel, has very little to offer in the way of alternatives except for the possible use of frequency instead of amplitude modulation. High fidelity is practicable with either

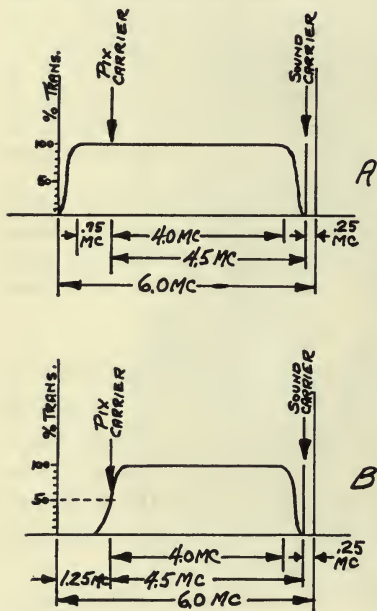


FIG. 1. Typical television channel.

method. The sound side is mentioned here only because of its relation to the rest of the channel and its consequent effect on remaining band width available for video information. Modifications in the location of sound and video carriers would result in slightly increased picture definition, but probably would add to receiver cost in an unreasonable ratio.

In constructing or reconstructing a television image, the functioning of scanning circuits requires a definite portion of time. This

\* From a statement by E. K. Jett, Chief Engineer for the Federal Communications Commission at the NTSC organization meeting, July 31, 1940.

interests us in considering resolution because, in one sense, it reduces the area on which we may resolve a given scene. Fig. 2 gives an idea of the relation between the total and useful areas presently employed. This illustration is in error principally by the actual beam retrace time which, in this instance, is quite small, thus giving the desired approximation. The unusable vertical portion is approximately seven per cent of the field interval and is approximately fifteen per cent of the line interval. These percentages have been found highly acceptable as a tolerance within which individual trans-

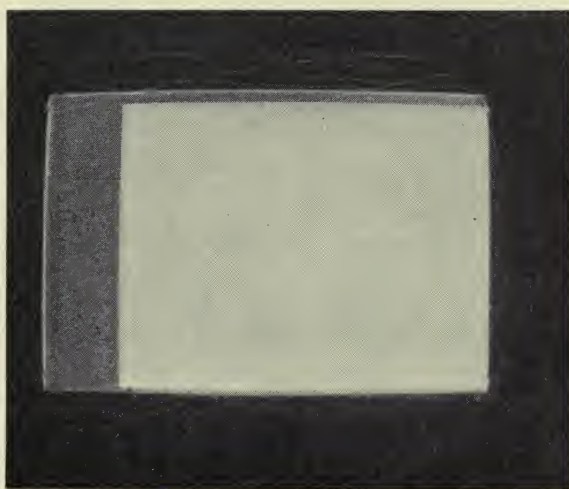


FIG. 2. Showing relations between total and useful areas now employed.

mitters and receivers are able to consistently operate. It will be noted that percentages of line and field intervals are used here to express time, as the actual time will vary with different line and field frequencies.

The type of wave-form which initiates the scanning sequence interests us in considering resolution because we depend upon it for accurate interlace and line register. The mind can conceive no end of possible wave-shapes and combinations, but only three seem to have received much industry attention. The first is that proposed by the Radio Manufacturers Association and shown in Fig. 3. The chief merits of this system of pulses are that there is considerable latitude in receiver circuit design; this type of pulse will control



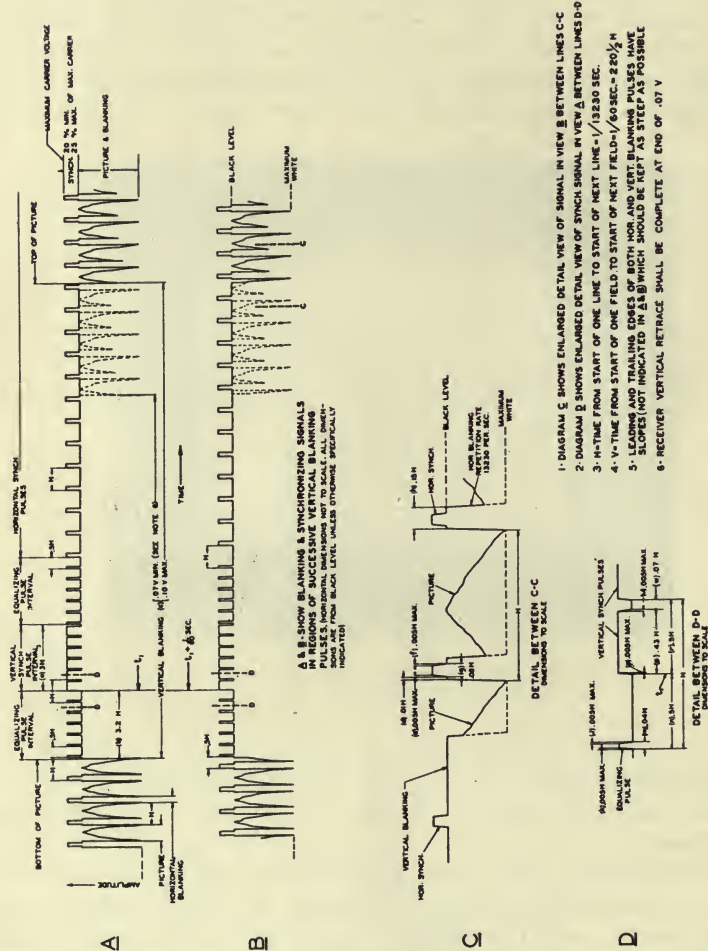


Fig. 3. RMA standard T-111 television signal; (441 lines, 30 frames per sec., 60 fields per sec. interlaced).

either driven or synchronized scanning oscillators; and has been proved satisfactory in use.

Fig. 4 is an oscillographic reproduction of the RMA field pedestal wave-form which may easily be obtained in practice.

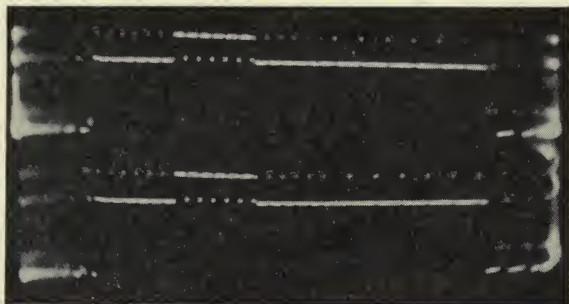


FIG. 4. Oscillographic reproduction of RMA field pedestal wave-form.

Fig. 5 is similarly reproduced, but shows a line pulse and pedestal with considerably greater clarity.

The second method is related to the above in that the same end-point is realized, but in a different manner. It has been proposed by V. A. Loughran of the Hazeltine Service Corporation that the ampli-

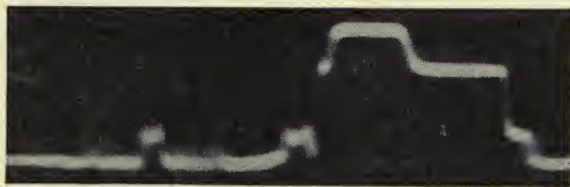


FIG. 5. Similar to Fig. 4, but showing line pulse and pedestal more clearly.

tude-modulated video signals be interspersed with different frequency-modulation excursions of the carrier for the line and field synchronizing signals. Fig. 6 shows how they propose to accomplish this. The advantages are an increase of picture signal equivalent to an increase of 60 to 70 per cent in transmitter power, a better sync amplitude margin over picture components, a better sync signal-to-noise ratio, and no "infra-black" level.

Fig. 7 is their block diagram of a receiver for this second method. The band-pass filters and amplitude selectors would seem to place

an added cost burden on each receiver purchaser over the first method described, to which there might well be some objections. The advantages mentioned, or the relative need for them, have not yet been confirmed by suitable field tests.

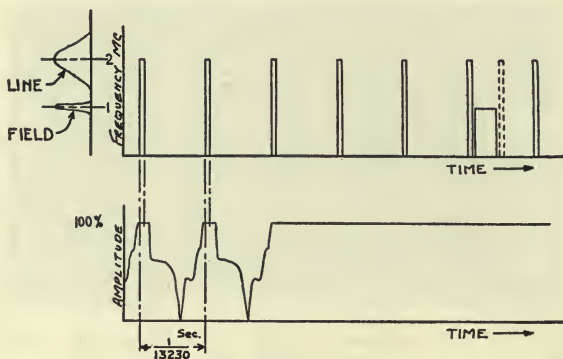


FIG. 6. Loughran's wave-form for initiating scanning sequence.

The third method is illustrated in Fig. 8, proposed by the Allen B. DuMont Laboratories. This latter method seemingly differs from the first method in only one essential respect—the substitution of a

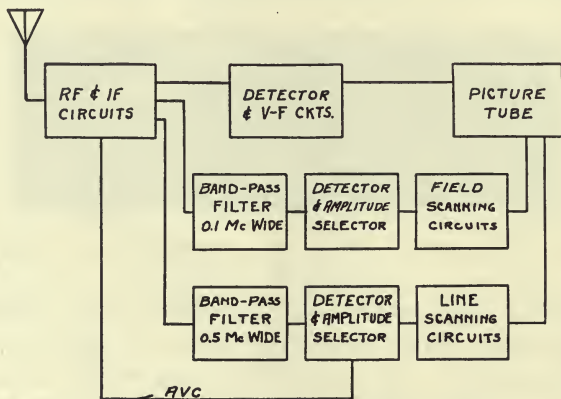


FIG. 7. Block diagram of Loughran's receiver.

train of relatively high-frequency pulses for the broad pulses and the elimination of equalizing pulses.

Another phase of the problem which has wide industry agreement is that odd-line interlaced scanning shall be used. This has the ad-



vantage of doubling the flicker frequency for a given frame frequency—among other things—and will probably be retained even in the case of color images.

Briefly in review, the number of elements composing a single frame divided by two, times the frame rate per second, determines the band width we have to transmit and subsequently utilize to reproduce the image.

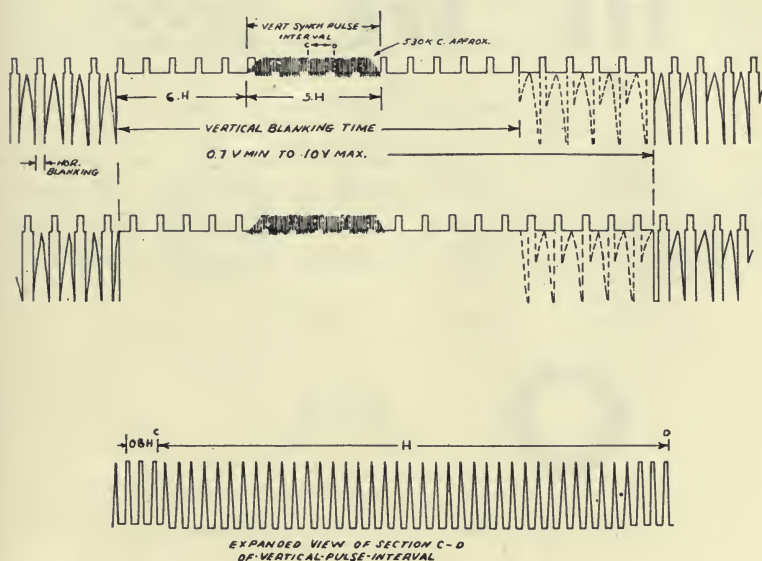


FIG. 8. Signal proposed by Allen DuMont Laboratories.

In order to get the greatest resolution in a single frame, a decision must be made as to the least practical number of frames per second. Two major problems are flicker and motional image smear.

Flicker in television differs somewhat from that in motion pictures in that there is continual scanning of lines from top to bottom, interlaced; each line in the sequence being brighter to the right than to the left, and each line in turn diminishing in brightness as another line in the scan is added. Special investigations of this type of flicker have led to the conclusion that approximately fifty interlaced fields (or twenty-five frames) are required to remove the sensation of flicker—which, as an end point, agrees well with motion picture practice.<sup>1</sup>

Motional smear or blur is not strictly confined to element displacement due to the progression of an object during the interlaced field scanning interval. To evaluate the importance of element displace-

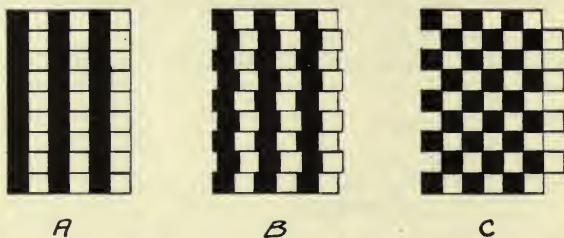


FIG. 9. Motional smear of element detail.

ment, Fig. 9 shows a group of idealized interlaced lines in which a group of tall objects of element width are scanned. In *B*, the objects have moved one-quarter of their width during the field interval. It is generally conceded that displacement beyond this amount be-

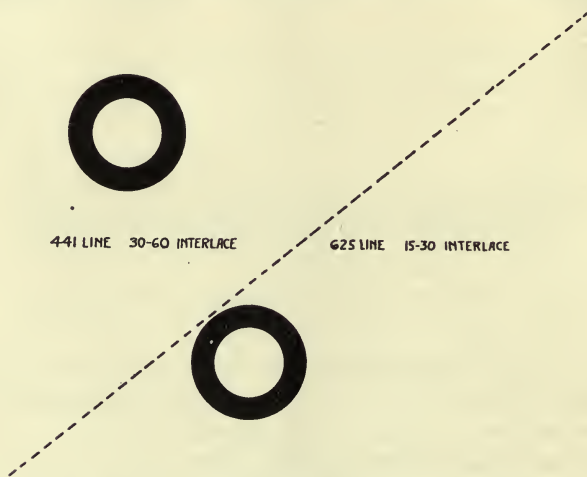


FIG. 10. Object for illustrating horizontal motional smear.

gins to destroy the fine structure of the image. *C* shows an extreme case where motional element displacement is equal to element width. As the total number of elements composing a frame becomes larger (*i. e.*, the number of lines increased), each element becomes smaller and the rate of permissible motion in a given field interval becomes less. Areas of element size may in this case be likened to grain in

motion picture film. It is proper, therefore, in considering motional smear to attach the greatest importance to the image repetition rate since element detail serves principally, as illustrated, to define the object itself rather than the position of the object in successive field scans.

It has been established as a physiological fact that the eye sees every moving object sharply. The optical axis of the eye stays focused on the moving object, and sees no unsharpness (except for other motions of parts of the object).<sup>2</sup> Within practical limits, sharpness in moving objects is a system requirement. Figs. 10 to 13

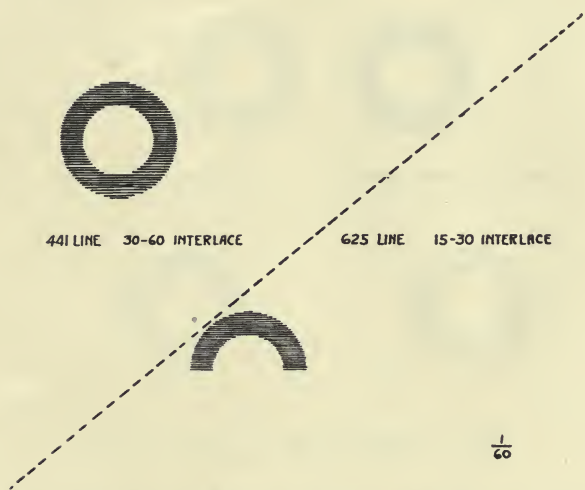


FIG. 11. Effect at the end of  $\frac{1}{60}$  second.

illustrate the effect, neglecting in the main a slight shape distortion of the object. Let us assume the object is the disk shown, and that it moves from left to right, and that the line of transit does not appreciably change the size of the object, which is approximately one-quarter the height of the frame.

At the present moment, there is some interest in the practicality of fifteen as against thirty frames per second, and the questions raised are not only on flicker, but on continuity of motion and motional smear.<sup>3</sup> Let us, therefore, compare the two.

With the disk in motion, these systems will scan as shown in Fig. 11 at the end of  $\frac{1}{60}$  second. The 30-frame system has scanned one field, and the 15-frame system, half a field.



At  $\frac{1}{30}$  second, Fig. 12 shows the 441-line 30-60 interlaced system has completed the scan of one frame. From this point on, its appearance will remain unchanged, due to scanning repetition.

At  $\frac{1}{15}$  second, Fig. 13 shows the scanning of one frame also completed for the 625-line 15-30 interlaced system. The object has travelled twice as far and the difference in smear is evident. What happens after this point is that in each system the object "creeps" by successive field displacements.

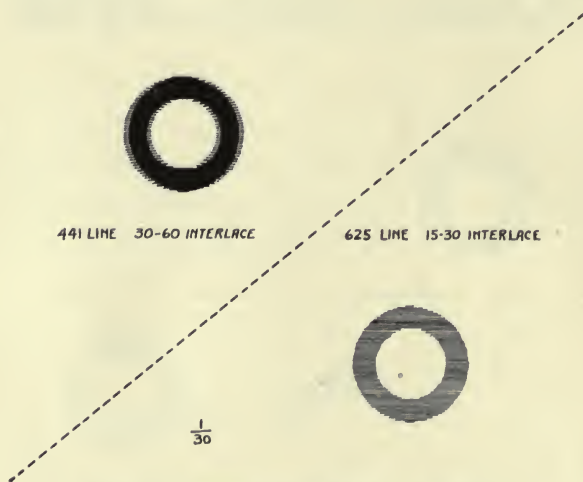


FIG. 12. Effect at the end of  $\frac{1}{30}$  second.

A somewhat similar effect would be obtained in the vertical direction.

In the example given, the rate of motion has been assumed slow enough to produce "simple smear." In the 30-frame case the rate of motion would have to be twice as fast as in the case of 15 frames to produce the greater degree of smear, or that still faster motion is required to produce the illusion of multiple or successive images.

Black-and-white television picture tubes at present used with the 30-60 interlaced system have what is considered adequate brilliancy in a semi-dark room, a relatively fast light decay characteristic, and depend on the scanning frequency to eliminate both flicker and motional smear.

Picture tubes have been proposed for the 15-30 interlaced system which would have a relatively slow light decay characteristic, the

intent being to diminish flicker. Assuming equal brilliance and color, it would appear that as the tendency toward flicker is diminished, the tendency toward motional smear would be increased, and *vice versa*, within the limits of the system.

It has been estimated that about one-third of the present 24-frame per second motion picture action shots are unnaturally reproduced.<sup>2</sup>

Considering all these factors, thirty frames per second is herewith recommended for black-and-white television images.

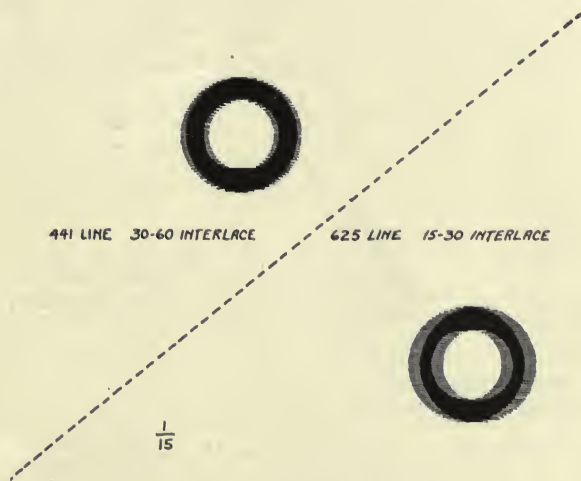


FIG. 13. Effect at the end of  $\frac{1}{15}$  second.

Before considering resolution in terms of picture detail, let us review a present system limitation of first importance. The electron beam used in scanning (both at the transmitter and receiver) has essentially the characteristic shown in Fig. 14. Due to the (approximately) cosine-squared intensity distribution in the spot, it is necessary to overlap the successive scanned lines in order to produce a flat field, by a factor which reduces the resolution to an amount variously estimated at from 53 to 85 per cent.<sup>4,5</sup> The correct figure is apparently in the neighborhood of 70 per cent.<sup>6</sup>

Dr. J. R. Pierce presented a paper "Rectilinear Electron Flow in Beams," before the Institute of Radio Engineers Pacific Coast Convention this fall, which—together with subsequent discussion—indicates that square or preferably oblong spot shapes of even intensity distribution are at present practical for commercial television camera

or picture tubes. The Bell Telephone Laboratories have constructed such a tube experimentally, and the results obtained verify that this is a correct approach to the ideal condition. The potentialities of this spot shape should be considered in determining standards.

To emphasize this point further, two illustrations are reproduced from a paper by Dr. P. C. Goldmark.<sup>7</sup> Fig. 15 is a direct reproduction of the original photograph. When this photograph is optically scanned with a slit aperture to simulate a 441-line 30-frame 60-field image transmitted within a 4.25-megacycle band, the result is Fig. 16. Much of the detail is element size or smaller, critically revealing the limitations of this finite scanning spot size, but eloquently testi-

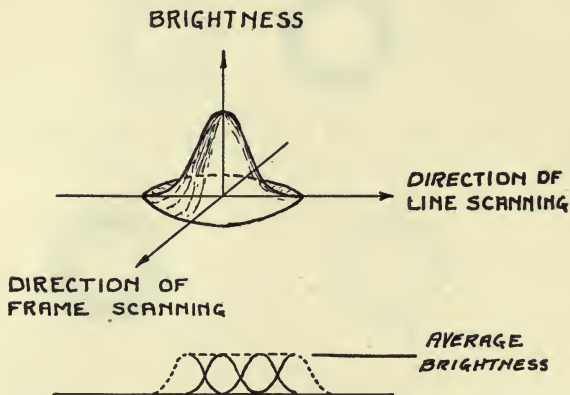


FIG. 14. Characteristic of electron beam used in scanning.

fying that television images, as received today, can be improved considerably before the maximum resolution of a 441-line system is achieved.

Table I presents an opportunity for some interesting comparisons. In computing the various numerical values shown, some minor assumptions were made which were the same in all cases, and hence serve for comparative purposes.

We should note parenthetically under the second column, which is for 441 lines, the values for vertical and horizontal resolution. By cutting down spot size slightly—though not enough to depart from an apparently flat field as far as the eye can discern—resolution can be increased to 300 vertically and 400 horizontally. Pictures with this degree of resolution have been transmitted on regular programs. Corresponding values in the other columns could likewise be



increased. This degree of excellence has by no means been an average condition during, say, the past year.

Higher order resolution is basically desirable to all. Those who have advocated 625 lines, 15 frames, with the present "cosine-squared" spot will doubtless welcome the previously mentioned developments, indicating an approach to equivalent results with a 30-frame image.

TABLE I

	30 Frame				15 Frame	
Number of vertical lines	343	441	507	525	625	735
3:4 Aspect ratio, H. elements	496	644	738	766	912	1071
Approximate band width in MC	2.5	4.2	5.6	6.0	4.2	5.9
Useful vert. lines ( 7% blank)	316	410	471	488	581	683
Useful h. elements (15% blank)	422	547	628	651	775	910
With Cosine-Squared Spot						
Vertical resolution	223	290	332	344	410	481
Horizontal resolution	298	387	444	460	548	643
Approximate band width in MC	1.8	3.0	4.0	4.2	3.0	4.2

It will be noted that 441 lines is indicated as the maximum which might be used with a better spot shape because of the band-width limitation. The actual scanning spot shape is a factor in the band width required, which may be greater or less than shown; if greater, some use may be made of the half megacycle which has been allowed for attenuation of video information between video and sound channels. This analysis is made on the assumption that element detail is to be continuously transmitted. While this assumption defines the ultimate excellence of a system, in practice this is by no means an average condition. Because of this, the selection of 507 or 525 lines might be warranted; this to approximate an image of the excellence indicated in the top bracket, not present practice.

Fig. 17 is a photograph of an image derived from a monoscope tube. In producing this particular image, a "cosine-squared" spot with 441-line 30-frame interlaced field scanning was used. This illustrates very closely the maximum resolution we can expect under these conditions and corroborates the values given in the previous figure.

It will be noted that the line scanning is properly overlapped, making it impossible to discern any departure from a flat field.

It might well be commented on here that some programs received in the past with this system (both in the East and West) have, as previously noted, been lacking in many respects. At various times,

observed definition has been low, conceivably due to receivers and their installation or operation; shading has been inadequate; contrast poor, possibly the result of experimental lighting, inadequate carrier modulation, or receiver adjustment; variations have been noted in synchronizing information; and (to cite a particular case) *W6XA0* has, in the past, been faced with the almost impossible task



FIG. 15. Original photograph from which Fig. 16 was reproduced (*Photo by Fairchild Aerial Surveyor*).

of eliminating vertical bars from the image occasioned by the physical proximity of *KHJ* on 900 kilocycles. *W6XA0* is now effecting a long contemplated change of location to Mount Lee, which will eliminate this difficulty. Again speaking in a national sense, some people have formed adverse opinions because of program material. None of these experimental difficulties are system limitations.

Another factor which we must take into consideration is the possibility that the public will not, in every case, actually purchase a television receiver capable of resolving maximum transmitted detail.



There are limiting items such as small picture tubes, which, of themselves, would not be capable of maximum definition. In addition to this, and perhaps more important, are savings to be effected by narrow band pass transformers or filters where the gain per stage is higher and less stages are required. The first result of such economies is a decrease in resolvable horizontal elements. The pattern shown,



FIG. 16. Result of optically scanning original of Fig. 15 with a slit aperture to simulate a 441-line, 30-frame, 60-field image within a 4.25-mc band (*Goldmark and Dyer*<sup>7</sup>).

and subsequent improvements thereon, can suffer considerable loss of horizontal definition (which the eye favors) and still give an acceptable ratio of horizontal to vertical resolution. It is submitted that this decrease in image resolution should be the result of purchasing an inferior receiver—much as a customer now makes his choice between, let us say, an excellent console radio and one of the popular midgets—rather than a system limitation.

If, for reasons previously mentioned, it might seem desirable to adopt a 507 or 525-line system, the ratio of horizontal to vertical



resolution for less costly television receivers would, for a given band width, be much less favorable. This fact must be seriously weighed against the advantages sought.

There are several problems associated with colored images which are well illustrated by previous examples given for black-and-white images.

In a recently proposed color system, sequential field scanning through rotating color filters has been demonstrated.\* In comparison with black-and-white images, there are two difficulties which can be adequately minimized by a substantially higher frame frequency for the colored images. To illustrate this need, in the figures previously used to show motional smear, we can mentally substitute

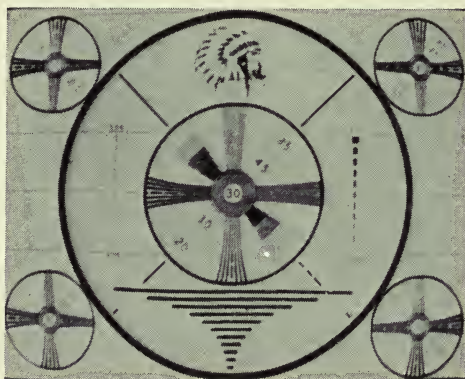


FIG. 17. Photograph of an image derived from a monoscope tube.

alternating and progressing fields of color. Mainly on the trailing edge of a moving object, a rainbow effect will result, its degree of prominence depending on the rate of motion and the colors of the moving object and its background. Also, in comparison to black-and-white images, the color flicker frequency is reduced, and for a given predominating color, such as a sky background, a higher frame rate is indicated.

Technical details to be overcome include loss of light in the color disk, both at the transmitter and receiver. In the receiver, a very rapid decay period must be used on the picture tube screen.

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\* At the studios of the Columbia Broadcasting System, New York, N. Y., September 30, 1940.

Due to present disparities between black-and-white and color systems, two separate standards are indicated. It is suggested that the standard for color be set when a system has received adequate field tests. Some component parts, both at the transmitter and receiver, are not necessarily identical or interchangeable.

Considering only black-and-white images in summary, and conceding that the art has by no means developed the full possibilities of any system, some latitude for development must, at this time, be provided. All presently proposed systems have a common minimum flicker and motional smear requirement, indicating for this country a 30-frame, 60-field, interlaced scanning sequence. The band-width limitation is not exceeded under present practice with a 441-line image, but it has been shown that it may well be exceeded as the art progresses. A possible compromise is indicated in the use of a 507 or 525-line image.

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## TELEVISIONING THE NATIONAL POLITICAL CONVENTIONS OF 1940\*

HAROLD P. SEE\*\*

*Summary.*—This paper describes the methods by which the National Broadcasting Company provided television coverage of the Democratic and Republican political conventions, for the benefit of the television audience in New York City and surrounding areas.

Due to lack of television transmission facilities between Chicago and New York, portions of the Democratic Convention were recorded on film. The film was sent to the NBC film scanning studio in Radio City and presented as part of the afternoon and evening television programs.

Portable television pick-up equipment was sent to Philadelphia for the purpose of televising the Republican Convention proceedings. The television signal was transmitted 104½ miles between the pick-up point and the NBC television transmitter in New York City by means of the coaxial cable facilities of the Bell System.

The National Broadcasting Company inaugurated regularly scheduled experimental television programs in the New York City area on April 30, 1939, when its television mobile unit cameras occupied a space on the camera platform at the Court of Peace, New York World's Fair. Thousands of persons in their homes miles away from the Fair Grounds, at Flushing, Long Island, were able to see and hear President Roosevelt dedicate the New York World's Fair of 1939. Between that date and January, 1940, these television mobile unit cameras were present at over ninety events of public interest occurring within a radius of twenty-five miles of the Empire State Building, where the receiver for relay work was located. Practically every phase of sports as well as most of the major news events occurring in New York City and its suburbs has been televised during these eight months.

The program management of NBC looked forward to the coming political conventions as a source of interesting television program material. It was hoped that both major parties would choose New

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\* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received November 7, 1940.

\*\* National Broadcasting Co., New York, N. Y.



York City as the site of their national conventions, and thereby make available to the television audience two of the most important domestic news stories of the year. They were mindful of the fact that only sixteen years ago, the then budding young radio industry had achieved great success at the Democratic Convention of 1924 when the vote of the Alabama delegation of "24 votes for Underwood," had echoed for days in New York's old Madison Square Garden, and had been heard by a few thousand early radio set owners as they passed around the head-phones.

The choosing of Philadelphia by the Republican National Committee early this year as the site of their Convention and that of Chicago by the Democratic National Committee for theirs, made the possibility of a direct television pick-up by NBC of a national political convention possible in only one case. The relay transmitters in use for field transmission could not have spanned the 90-mile distance between New York and Philadelphia, and other relay links under construction could not have been made available in time. The number of television relay transmitters required to establish a 900-mile circuit between Chicago and New York could not have been assembled and tested in less than two years. A coaxial cable installed a few years ago between the Bell Laboratories Building at 32 Sixth Avenue, New York, and the Bourse Building at 4th Street, Philadelphia, was the only means of a television relay. This cable had been installed for the experimental study of multicarrier telephony. The original band-pass characteristic of its associated repeaters had been established at 1000 kilocycles. Such a frequency band is not sufficient to convey a television image of good definition. Inquiries made of the Bell System engineers revealed that they were at work on a planned extension of the band-pass characteristic to 2800 kilocycles. An amplifier having such a frequency characteristic and minimum phase delay is capable of transmitting sufficient of the video frequencies comprising a 441-line television picture to result in an image of good definition.

A survey was made at Convention Hall to determine the practicability of adapting the NBC television field equipment to the use of the hall planned by the arrangements committee. Tentative permission was secured to televise the proceedings of the Convention. The engineers of the Bell System welcomed the opportunity of putting this cable to a practical test as the first television cable network link in the United States.

The first problem confronting the engineers engaged in this pioneering attempt was establishing some method of connection between the New York terminus of the cable at 32 Sixth Avenue, and the Radio City television control room, which are six miles apart; and the connection between the Bourse Building at 4th Street, Philadelphia, and the Convention Hall at 32nd Street, Philadelphia. The latter points are three and one-half miles apart. It was originally planned that the two ultra-high-frequency transmitters operating in conjunction with the regular video equipment used in the New York City area would be used to span these gaps. This plan was rejected in favor of an attempt to use the experience gained in experimenting with specially selected highly equalized pairs among the regular underground telephone facilities of the Bell System. Several programs had been transmitted between Madison Square Garden and the television control room on the fifth floor of the RCA Building in New York. This distance is slightly less than two circuit miles. Through the use of the equalizers and repeaters a good degree of success had been achieved.

Two of these twisted-pair circuits were set up with repeaters at one-mile intervals between Convention Hall and the Bourse Building and between the Bell Laboratories Building and Radio City. The entire circuit was electrically adjusted and tested by the Bell System engineers over a period of two months. Portable television pick-up equipment was shipped from Radio City to Philadelphia and used for test purposes. The first test picture was transmitted between these two eastern seaboard cities on June 14, 1940. With a cable connection established between the Convention Hall and Radio City it remained for NBC to use its limited amount of field equipment to the best advantage in covering this news event side by side with radio broadcasting and newsreel facilities.

During the preliminary surveys made at the Philadelphia Convention Hall, committee members in a sincere desire to coördinate facilities, suggested that television cameras occupy a space on the newsreel camera platform. This suggestion was taken under advisement but in view of the dissimilarity of equipment adaptation and the divergent modes of operation of the newsreel and television systems, it was decided that a special television platform should be constructed. It has often been freely stated that television is a marriage of radio broadcasting and motion pictures. While this may seem to be true in a broad sense, and in the mind of the television viewer as he watches

scenes occurring at points remote from him, the practical operating requirements at the present state of the television art, and especially in field work, are of necessity quite different from those of the news-reels. These differences were very well exemplified at the Philadelphia Convention. It is, of course, quite probable that the furtherance of the television art and improvements in pick-up tubes may change the complexion of this matter especially as regards optical systems, but the modes of operation will remain basically different.

The television camera at the present time must be located in such a manner that it achieves the greatest possible radius of action from one position. It is, for all practical purposes, tied down to one position by its cable connection to the control equipment. This is qualified to some extent when the location is in an open space and sufficient slack cable may be left to allow movement of the camera on a movable platform, or a change in its position while another camera takes over the operation. Under conditions such as existed at the Convention pick-up, where the camera had to be located on a platform, little or no change in position is possible.

There are three television pick-up tubes commercially available. These are the large Iconoscope, the small Iconoscope, and the Orthicon tubes. The large Iconoscope sensitized surface is 4.81 by 3.62 inches, the small Iconoscope 3 by 2.75 inches, and the Orthicon 2.33 by 1.74 inches. All three tubes are in use in NBC television field equipment. A large Iconoscope camera and an Orthicon camera are used with the Telemobile Unit, while two small Iconoscope type cameras are used with the transportable equipment.

While the operating sensitivity of a pick-up tube may be affected by a number of factors and a direct quantitative comparison of tubes is difficult to make, it has been found that the Orthicon tube is more sensitive in practical operation than either of the other two types. This is particularly evident when the overall brightness of the scene is low. The characteristics of this tube are explained in the October, 1939, issue of *RCA Review* and in the July, 1939, issue of *Electronics*.

In consideration of the fact that operation at Convention Hall was to take place under artificial illumination, the Orthicon represented the only tube usable under these conditions by which close-up pictures from a distance could be obtained with commercially available optical systems.

From the dimensions previously given, it is seen that the sensitized surface of an Orthicon tube is much greater than that of the 35-



mm film. In order to obtain an image size proportionate to the area, a television camera equipped with an Orthicon tube must use a lens which has approximately 2.7 times the focal length of that in use in a newsreel camera when the two cameras are located at the same distance from the subject matter. If the lens speed is to be retained under these conditions, the lens diameter is also increased by a factor of 2.7. In most lenses suitable for our purposes, these considerations involve lens diameters of magnitudes which are not commercially available and whose prohibitive cost for special construction render them economically unfeasible. Lenses may be constructed in certain large-diameter ranges without correction for chromatic aberration. The use of such a lens would, of course, leave much to be desired. If the lens diameter is not increased, a loss factor of approximately 7 in mosaic illumination will result when the focal length is increased by a factor of 2.7. It is therefore evident that a television camera using the smallest mosaic area now available should seek a location closer to the subject matter than is necessary for a newsreel camera.

At the present time, a camera capable of housing the Orthicon tube, magnetic focusing coil and deflection coil, video and deflection amplifiers, is 28 inches long. When this camera is located at a distance of 50 to 60 feet from a speakers' rostrum, a 20-inch focal-length lens is the minimum that may be used in order to achieve a semi-close-up view of the average man. The addition of this lens to the camera results in a unit 4 feet long. It is inconceivable that such a unit could be crowded together with five newsreel cameras on an average-size camera platform and still not be impeded or interfere with the other cameras when panned in an arc of 60 degrees.

Film editing is done in a matter of hours after the scene recorded has passed into oblivion and become history. By accepted methods, scenes may be taken in any sequence, sound added, and the final result shows the highlights of an event in a few short moments. It is therefore possible to show many varied scenes and yet not have used more than one or possibly two cameras.

Television editing is a matter of instantaneous decision, and is achieved by electrically switching to another camera system, which may be focused on the previously shown scene but using either a wider or narrower lens system. It may also be a camera located at some distance away from the first one used. Television operation is a continuous proposition, and therefore more facilities must be available to maintain varied coverage of a particular event. Mistakes in

the motion picture industry are found in the cutting room while mistakes in television operation are seen in the living-room.

In order to have covered the Convention in a manner comparable to the combined facilities of the radio broadcasting and newsreel companies, we should have found it necessary to place a minimum of six cameras at the Convention Hall and two or three more at the various headquarters of political groups in the city.

The Convention was the first indoor event wherein newsreel and television cameras were to be focused on the same action over a period of hours and days and yet maintain diametrically opposed visual coverage from one minute to the next. Lighting at this Convention therefore had to be considered from the television standpoint as well as that of the newsreels.

As distinguished from newsreel operation, television operation is a continuous performance and thus the lighting for television must be continuously maintained. It is possible for newsreel cameramen to make the best use of their flexibility in editing by filming the keynote address or at least the highlights of this speech on the day before the opening of the Convention. This arrangement is made with the keynoter. The cameras are set up on the floor below the speakers' rostrum. When the keynote speech is actually given, during the Convention, the newsreels may have the light units in the hall spread upon the seated delegates, and make "shots" of the audience reaction to the keynote address. This is the first glimpse that television has had of the keynote speech, and the speaker must be adequately illuminated for the television cameras. In like manner, during nominating and seconding speeches, the newsreels may, if they desire, take only excerpts of even the most important speeches. Armed with advance script, they may take only those portions in which they are interested. These are the highlights. For such operation, it is not necessary that continuous high-level lighting be maintained. For television purposes, a threshold of illumination must be maintained on the speakers' rostrum at all times.

Sufficient lighting for television was maintained at Philadelphia by increasing the specifications for fixed lighting used in the same hall in 1936. Ten 5-kw solar spotlights were suspended from the ceiling and two similar 5-kw units were located on each balcony. The overhead lamps were mounted on a frame above and in front of the speaker. This source of light provided an illumination of 800 foot-candles incident on the speakers' platform.

Eight 150-ampere d-c arc lamps were installed at points on the balcony so that they could be directed to any spot on the floor for both newsreel and television purposes. These lamps were used to illuminate an area on either side and in back of the speakers' rostrum when the newsreels wished extra illumination in that vicinity. When the center of interest was transferred from the speaker to the state delegations, such as during balloting for candidates, the television cameras followed the beam of the arc lamps. If the television program director desired that the cameras be focused on the speakers' rostrum while the newsreels were still shooting scenes of the floor, the threshold of illumination provided by the fixed lights focused on the speakers' rostrum was still maintained for television operation.



FIG. 1. Unit 1A parked in front of Radio City on occasion of sidewalk interviews.

The television field equipment available for use at the Philadelphia Convention consisted of Telemobile Units 1A and 1B and the transportable, or suitcase type of equipment. Telemobile Units 1A and 1B are each 10-ton motor vehicles and are 26 feet long. Telemobile Unit 1A contains the video and audio equipment which operates in conjunction with one television camera employing a standard Iconoscope pick-up tube and one camera using an Orthicon tube. The equipment, which consists of a synchronizing generator, deflection amplifiers, control amplifiers, line amplifiers and monitors, and audio system is mounted on nine racks situated on the centerline of the vehicle in the long dimension. All cables and accessories necessary for the operation of this unit are carried within the body. Telemobile Unit 1B contains a 400-watt ultra-high-frequency relay transmitter licensed to operate within the channel 162-168 mc monitoring equipment, and cable accessories (Fig 1).



The transportable, or suitcase type of equipment, consists of eleven boxes of an average weight of 50 pounds each. When interconnected, this equipment provides two television cameras employing the small type Iconoscope, a synchronizing generator, amplifiers, monitors, and



FIG. 2. (*Upper*) Orthicon camera on camera platform of Convention Hall.

FIG. 3. (*Lower*) Another view of cameras at Convention Hall. The Iconoscope camera is at the left.

a low-powered ultra-high-frequency television relay transmitter licensed to transmit in the channels 282–288 mc and 288–294 mc.

The Telemobile Units were constructed in 1937 and placed in operation in 1938. The transportable equipment was placed in operation in the fall of 1939. Several distinctive features which are the result of improved design at present prevent the cameras of one set of equipment from being directly connected to the video and control apparatus of the other.

The provision of an all-cable circuit between the pick-up point and Radio City, as previously outlined, obviated the necessity for considering the radio-frequency transmitters as part of the equipment necessary for transmission from Convention Hall. The low-power transmitter was held in reserve together with its associated receiver,

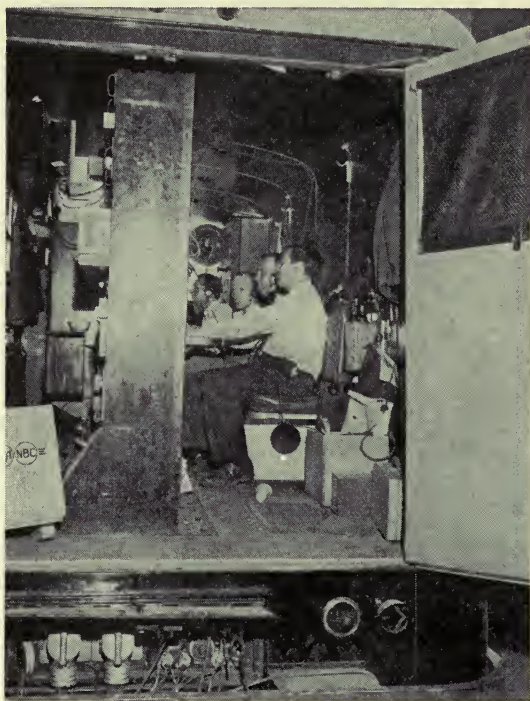


FIG. 4. Interior of telemobile unit 1A parked on freight-loading ramp at Convention Hall. View shows engineers and producer.

to provide for any contingency, such as the possibility of an acceptance speech being delivered by the party's candidate at a large outdoor stadium nearby. In that event, this transmitter would have provided the link to the cable termination at Convention Hall.

The purpose of televising the proceedings of the Convention was to bring to the television audience the greatest possible amount of program material on as wide a scope as was consistent with equipment and personnel limitations. The Main Hall, in which the 1000 or

more delegates and their alternates were seated under their identifying State banners was the focal point of interest as speaker after speaker mounted the rostrum to address the assembly. The main entrance to the Hall was another point of interest as the crowds gathered to watch nationally known figures disembark from taxis and enter the auditorium for each of the many sessions occurring during the five-day Convention. The possibilities of providing a space where news commentators, political figures, and others might be interviewed before the television camera, was considered as an important addition to the existing program sources.

A television camera platform was constructed on the south balcony of the main arena at a distance of 60 feet from the speakers' rostrum. The platform was 8 by 5 feet and was designed to accommodate two cameras, two camera operators, and an announcer. The camera faced the speakers' rostrum at an angle of approximately 45 degrees, and looked down at it from an angle of approximately 10 degrees. The position of the platform was predicated upon the already chosen location of the newsreel camera platform and a compromise between our distance from the speaker and the angle at which the camera faced him. The newsreel platform was placed at the same proportionate position that it had occupied during the Democratic Convention held at the same hall four years ago. The television platform was 15 feet forward from the newsreel platform. With both these platforms built out from the balcony on the speaker's left, the 15-foot dimension allowed sufficient spacing to prevent the television camera platform and equipment from obstructing the view of the newsreel cameramen located nearest the balcony when he was using a 30-degree angle lens with his equipment (Figs. 2 and 3).

The two cameras associated with the Telemobile Unit were mounted side by side on this platform. A  $19\frac{3}{4}$ -inch focal length  $f/4.5$  magnesium fluoride treated lens was used on the Orthicon camera. The angle of view included a space approximately 3 feet either side of the speaker. When viewed on a 12-inch Kinescope, a bust view of the speaker occupied 5 inches vertically. The Orthicon was also used to pick up floor scenes during the balloting and demonstration parades which followed the placing of a candidate in nomination. The Iconoscope camera was equipped with an 8-inch focal length  $f/2$  treated lens. The wide angle of this lens included almost the entire width of the stage when focused on the speakers' stand. When focused on the floor, this lens showed more than half of the State



delegations. The sensitivity of the Orthicon enabled it to be used satisfactorily on scenes having a lower light level than used on the speakers' stand.

The large mobile unit containing the video equipment necessary for the operation of the main hall Iconoscope and Orthicon cameras was parked on a freight-loading ramp one floor below the main arena and inside the Hall proper. Circuit constants of the equipment and other factors limit the distance possible between the cameras and the mobile unit to a length of camera cable not exceeding 250 feet. Spe-



FIG. 5. Transportable type camera used in specially constructed studio. View shows Mrs. Wendell Willkie being interviewed by Mr. A. H. Morton, NBC Vice-President in charge of television.

cial holes were cut in the concrete floor in order to provide a path for the camera cable which would not exceed that limitation (Fig. 4).

A television studio was constructed on the second floor of Convention Hall. An unused dressing room was converted into a studio for interview purposes and a control room adjoining it. The transportable equipment was located in this control room. One of the small type Iconoscope cameras was used in the studio. The studio was located so as to be readily accessible to staircases, elevators, the speakers' platform, and the State delegations. Three 5-kw portable lighting units were used to provide illumination in the studio. Air-conditioning apparatus was installed to overcome the heat generated by these lights and the warm June weather outside. The control

room was left windowless in order to provide an ideal condition for viewing pictures on the Kinescope monitor. The other small camera was set up at the main entrance to Convention Hall which is 750 feet from the studio and its control room. This position was used during the daylight hours to show activities occurring there when there was little or no business being transacted in the Convention Hall. It was always used at the opening of each program (Figs. 5, 6, and 7).

In addition to televising the Convention and transmitting it to the television audience in New York State and surrounding areas of New Jersey, Connecticut, and Pennsylvania, provisions were made to satisfy the overflow of the general public which could not gain admittance to the Main Hall. The RCA Victor Company installed sixty television receivers in a large room set aside for public viewing. Receivers were also installed at the temporary Convention Hall offices of the three leading national press associations and a Press Club Room. The picture signal and sound to these receivers were transmitted by means of cable.

Over two miles of wire were installed in Convention Hall by NBC to supply power necessary for operating the television mobile units, power for lighting, air-conditioning, and teletypewriters in the studio and office, video circuits, audio circuits, sound monitoring, and communication circuits. This wiring was exclusive of those facilities which were installed by the Telephone Company within the building for our purposes. Such circuits included the audio connections between the mobile unit and the main frame, morse circuit, private line connection from the mobile unit to the Telephone Company's video control equipment in another part of the building and an ordinary business phone circuit. A breakdown of our temporary wiring installation shows that 2155 feet of coaxial cable and 1250 feet of camera cable were used. The remainder is divided between communication, audio, and power wiring facilities. These figures are included in order to indicate the magnitude of a temporary television pick-up at an event of this character. Many of our regular routine pick-ups in New York City at which permanent wiring facilities do not exist necessitate the temporary installation of close to one mile of wiring for a one-hour program.

It has been previously mentioned that differences in the equipment do not permit the ready interconnection of either pair of cameras with the corresponding control equipment of the other. In order to coordinate these cameras and provide smooth continuity of the program

as the points of interest changed from the program standpoint, it was necessary that a rapid switching system be devised whereby the video



FIG. 6. (*Upper*) Transportable control room. View shows all control equipment.

FIG. 7. (*Lower*) Scene showing transportable type camera in use at Main Entrance to Convention Hall.

signals from the transportable and mobile unit equipment could be transmitted to the NBC control room in New York City *via* the coaxial cable as well as to the special receiver monitor positions in other parts of the building.



The complete video signal contains picture signals, blanking pulses, and synchronizing pulses. Both the transportable and mobile unit equipment are complete units, and their outputs contain the signals referred to. In addition, it must be borne in mind that each set of equipment had its own synchronizing generator. These two systems were, of course, not identically synchronous with each other. Had it not been for program commitments in New York which kept the mobile units busy up until a short time prior to the Convention, there would have been nothing to prevent a system's being devised whereby the basic pulses from one generator could be used to control the other. In standard RCA television equipment, of which the Telemobile Units and the transportable equipment are an example, the video signal and blanking pulses are fed to an input tube in the line amplifier. The synchronizing signal is fed into its own input tube in this amplifier. The resultant complete signal is the television signal which is transmitted. In the case of this installation the main feed to the Telephone Company was transmitted from the line amplifier in mobile unit 1A. The monitors in the Telemobile Unit received their signal from a separate output tube in the line amplifier. This signal was also transmitted to another line amplifier which in turn fed two circuits. One circuit went to the sixty receivers in the public viewing room, and the other to the three receivers in the Press Offices and the single receiver in the Press Club Room. A switching system was devised so that the total output of the transportable equipment located on the second floor of Convention Hall was available at the input of the main line amplifier at the mobile unit so that this amplifier could receive either the outputs of the mobile unit cameras or the outputs of the transportable equipment cameras as represented by the combined transportable equipment signal. In this manner a four-camera pick-up was obtained. The ratios of synchronizing signals and blanking pulses in the mobile unit and in the transportable equipment control room were established by engineers in communication with each other by private line, so that the overall ratios transmitted to the Bell System, the local monitors, and the special monitoring positions were identical.

The audio system for television at this Convention presented little or no problem. The three major networks had combined their resources to obtain pick-ups from the fifty-three floor positions available for each of the state delegations. Each network provided its own pick-up at the speakers' rostrum. The network feed from all

these points was suitably attenuated and transmitted to one mixer position on the audio panel in Telemobile Unit 1A. Microphones were placed on the camera platform in the main hall, in the television studio, and at the street position.

Telemobile Unit 1A was designated as the master control point for the entire system. Three television engineers and a program director constituted the personnel at this point. One engineer was located in the control room associated with the studio. Engineers were at each camera position. The private line communication facilities necessary to interconnect all these points, plus providing communication between the Bell System control room, the NBC network control room, the public viewing room, and the mobile unit surpassed any communication installation set-up to date for either radio broadcasting or television. The master system was subdivided so that the video engineers and camera engineers at the mobile unit were able to converse without interference from conversations going on between video engineers and camera engineers at the transportable equipment. On a separate ear-phone, however, calls could be established between these two circuits after a switch was thrown. The same sort of system was carried through in the case of the audio engineer to the public viewing room, *etc.* The program director at the mobile unit had a separate communication circuit to his assistants at the camera positions.

The announcing technic in television is considerably different from that practiced in radio broadcasting. It is customary in sound broadcasting for an announcer to maintain a running comment, and bring to his listeners, through words, that which they can not see. In television, the running commentary is unnecessary. In the main hall the sequence of events on the speakers' stand and among the delegates not only predetermined the sound coverage but in many cases dictated the movements of the cameras. The only time that the announcer in the main hall was heard was during lulls, or when events occurring within the range of the camera needed some special explanation. The program director, located in the mobile unit, was able by means of the monitor system, to see the scenes on which both cameras were focused. According to his discretion, and predetermined program plans, he directed both television camera operators and the announcer, when the order of events did not logically predetermine both the visual and aural coverage.

Perhaps the most rapid-fire television editing by means of elec-

trically switching cameras equipped with different lens systems occurred when ballots were taken. As the Chairman called the name of the State delegation, he was seen by means of the Orthicon camera. A switch was then made to the Iconoscope camera equipped with the wide-angle lens. This camera was focused on the general floor scene. As soon as the switch was made, the Orthicon camera operator panned his camera to pick up a close-up scene of the State delegation. As soon as this had been brought into focus it was switched to the line amplifier, *etc.* By means of the intricate communication facilities, camera operators, directors, announcers, and video control engineers were at the peak of their coöperation during these balloting periods.

In addition to the communication facilities, it is NBC practice to provide a head-set at each point remote from the main control position by which members of both the program and engineering staffs are able to hear the sound transmission accompanying the picture. This system is known as "feedback monitoring." A loud speaker system in the mobile unit is used by the video engineers and program directors. By means of this monitoring system, the announcer may lead the camera by his description and other expressions which will indicate the content of the scene to follow.

While the position of all our facilities could not be determined until the Convention Committees had formulated all their plans, it was not possible for the Bell System engineers to delay their additional installations and tests necessary before the cable would be usable. They started their work in April. The special twisted-pair circuit was terminated in the Telephone terminal room on the northwest corner of the Convention Hall Building. At a later date, when the position of the studio, camera platform, and other factors had determined the location of the mobile units, a connection had to be made between the terminal room and the mobile unit; 750 feet of flexible coaxial cable was needed to complete this installation.

The completed picture signals from all four cameras were transmitted to the terminal room over the 750 foot piece of cable. At the terminal room the Bell Laboratory engineers were equipped with a monitor, an amplifier, and a video equalizer. Two special twisted-pair circuits had been installed between the Convention Hall and the Bourse Building. There were two repeater stations on these circuits. One was at the University of Pennsylvania, and the other at the Spruce Central Telephone Office. These picture circuits and repeaters were capable of transmitting a band of frequencies from 30 to



2,800,000 cycles per second. At the Bourse Building, a carrier system was used. The video signal was transposed so that the lowest frequency being transmitted through the coaxial cable and the twenty repeaters between Philadelphia and New York was of the order of 300,000 cycles per second. At the New York terminal of the cable, this signal was restored to the normal video range, and placed on two separate twisted pair circuits and transmitted simultaneously to the NBC television control room in Radio City. One circuit was of the same type as that used between Madison Square Garden and Radio City, and the two between Convention Hall and the Bourse Building. This circuit required repeaters at approximately one-mile intervals. They were located at the Watkins, Longacre, and Circle central offices. The second circuit was a special shielded cable undergoing tests at the time. Intermediate amplifiers were not required on this circuit even though its length was approximately 4 miles. In all, the picture signal travelled  $104\frac{1}{2}$  miles between the pick-up and the Empire State Transmitter (Fig. 8).

The combined facilities of NBC and the Bell System were used for a total of 33 program hours during the 5-day Convention. Persons and events heretofore known to many and yet seen by few were made available in close-up upon the many television receivers in the New York area. The Convention's candidate became the first presidential nominee to be seen by a television audience as he acknowledged the greetings of the delegates.

Faced with the lack of either radio-frequency or coaxial cable relay facilities between Chicago and New York, all thoughts of the direct pick-up method of bringing the proceedings of the Democratic Convention to our television audience had to be abandoned. The original consideration of obtaining special motion pictures at each session of this Convention and transporting them by air express to New York for television film scanning was adhered to.

The New York television audience was provided with scenes of the first day's activities of the Democratic National Convention held at Chicago, June 15th-18th, within 24 hours of the beginning of the first session. Special newsreel releases were made up for NBC by a newsreel company. At the end of each day's session, these newsreels were flown to New York. Developed and edited the next morning, they were available for film scanning as a part of the regular afternoon NBC television programs. The same releases were shown on the regular evening television programs.

While this method of coverage was not immediate, and lacked some of the spontaneity felt by televiewers who looked on the Philadelphia Convention, several scenes were available which had no parallel at

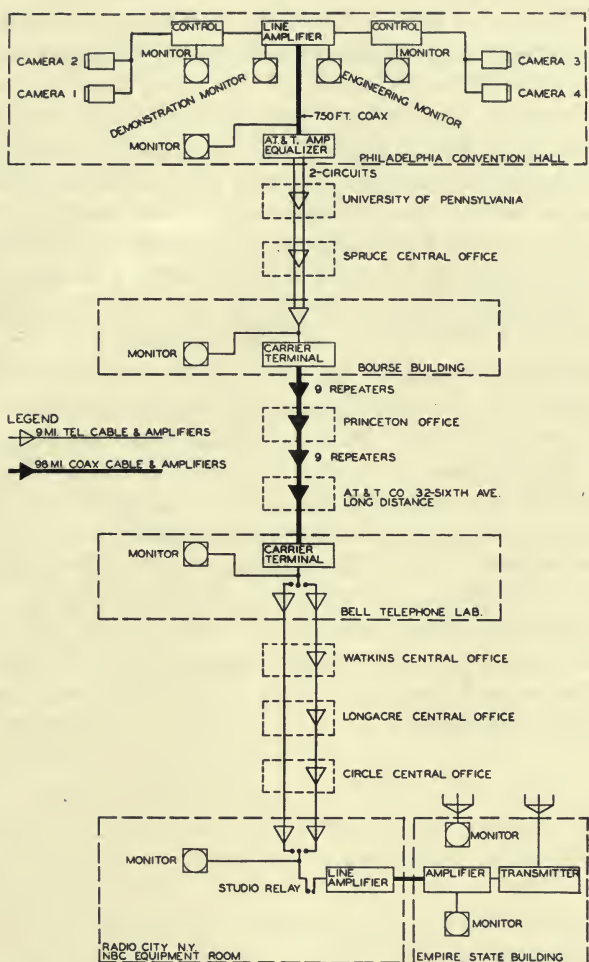


FIG. 8. Diagram showing circuit routing of television signal from Convention Hall to Empire State Building.

the Philadelphia pick-up. The motion pictures included not only scenes within the Hall, interviews with nationally known political figures, and street scenes, all of which were provided by the television

cameras at Philadelphia, but included pictures taken at the headquarters in Chicago of the many potential candidates, the arrival of colorful figures at railroad stations and other "atmosphere shots." The mobility of a small number of motion picture camera units was evident. \* This is, of course, in direct contrast to the lack of flexibility of the television cameras at Convention Hall, and bears out the contention made in the early part of this paper that from six to ten television cameras would have been necessary at Philadelphia in order to have been able to present the wide and varied coverage of an event of this character in like manner to that of the newsreels.

It is estimated that the television audience witnessing the scenes attendant to both the Republican and Democratic National Conventions of 1940 numbered in excess of 40,000 persons scattered over an area of 10,000 square-miles. Persons located over 300 miles distant from Philadelphia were able to see and hear events happening in that city through the combined facilities of the NBC television field pick-up equipment, the Bell System coaxial cable between Philadelphia and New York, the NBC television transmitter atop the Empire State Building tower in New York City, and the special receiving equipment and television transmitter of the General Electric Company, located just outside the city of Schenectady, N. Y. The latter station rebroadcast most of the NBC programs in the Schenectady area. The Philadelphia transmission, which was the 175th NBC outside television pick-up since April, 1939, was the forerunner of future television network operation and provided the earliest television cable network facilities in the United States with their first practical operating test.



## MOTION PICTURE EDITING\*

I. JAMES WILKINSON AND W. H. HAMILTON\*\*

*Summary.*—The paper is an attempt to reduce to words a portion of the mechanical and artistic elements involved in the process of editing a motion picture. The authors realize that they are dealing with a highly controversial subject but feel that, as there is so little pertinent material available on this phase of motion picture production, this paper may serve as a preliminary to a study on a larger scale.

Consideration is given to the origin of film editing and its advancement from the purely mechanical craft of the early days to its present status as a contributing factor in the entertainment and dramatic values of the motion picture of today.

It is a far cry from the old nickelodeon theater of the early nineteen hundreds to the modern, streamlined motion picture palaces of 1940. The business of editing pictures, which is now an important phase of the industry, was at that time unknown. In the beginning, it was the duty of the cameraman to screen the negative, cut off the number plates, arrange the film in continuity, and have it printed at the laboratory. This work necessitated long hours for the cameraman, and damaged the negative by running it through the early type of projector. The "cutter" was first introduced to the film industry as a young man whose duty was to assist the cameraman by cutting off the scene-number plates and prepare the negative for printing. Because the boy used a pair of shears to snip out fogged pieces of negative and to remove the scene-number plates, he became known as a "cutter." In the early productions, all the scenes were long shots, requiring only a few narrative titles identifying the locale as Niagara Falls, for example, and telling the audience that Mary and Joe were on their honeymoon, etc.

Competition among the producers was about as keen in those old days as it is now, and each was staying awake nights trying to think up new ideas for improving his product. One enterprising producer conceived the happy idea of having his pictures talk. He used a

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\* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received October 12, 1940.

\*\* RKO Radio Pictures, Inc., Hollywood, Calif.

talking machine next to the screen, mechanically driven by the projector, but this proved impracticable. Another producer, not to be outdone, decided to make his actors speak dialog, and so developed the use of "spoken" titles. This advancement brought the cutter into his own, requiring him not only to write and intelligently edit the spoken titles, but thereafter to "cut" them into the proper place in the scenes.

As the film story-telling technic developed, the responsibilities of the cutter increased. The industry continued to advance, progressing through many stages: the early short subject, purely action and pantomime; the two-reel short, with pantomime and narrative titles; the first feature pictures of about three reels with spoken titles; the five-reeler, with more elaborate sets; then the filming of full-length plays and novels; after that came the "super-colossals." The cutter had been learning and progressing, step by step, with the industry. But now came sound, and with it an entirely different technic was demanded of him. The actual piecing together of film is generally taken for granted by the public. . . the mechanics of setting the stage—the introduction of the characters—their purpose in the scene—and their relation to each other. For example, the opening of a scene might go like this:

First, there would be a long shot of a country railway station—so we know we are not in the city, or China, or on a lake. Then comes the close-up of the name of the station—Glens Falls, N. Y. Over this we can hear the distant sound of a train approaching. Now we know we are in the country. From the Glens Falls, N. Y., sign, we pan down to a full shot of an old family horse and carriage. A small boy and a man are seated in the carriage. A close shot, just holding the boy and the man, finds the boy saying: "Well, here comes the train, Dad." This is done to tell the audience the sound they hear is a train coming and that the man is the boy's father. Now we want to see what the father looks like, so we show a close-up of him. He notifies us that the train is on time and he is sure that the boy's sister will be glad to be home from college. Now a fairly long shot showing the train coming to a stop. A closer shot shows a pretty girl standing on the platform. This would be Lana Turner, waving a college pennant in one hand and her sweater in the other.

While on the subject of close-ups, it might be well to discuss this most misused piece of film. One can find too many close-ups of the entire cast scattered throughout every scene in any show. When one

inquires the reason, the answer is something like this: "Rhythm;" "To keep it alive;" "The old man likes them;" and so on. As a matter of fact, on the production line, the ordinary director has had little time to learn his trade, so he gets the cast onto a set somehow, makes a close-up of each actor speaking his lines, and leaves a little room on the end of one for a fade-out. He has saved a half-day on the schedule, and the Front Office is pleased. But the picture generally "flops."

There is, however, a very special reason for the use of close-ups. In a recent picture, the director had a big courtroom scene. The accused man was being questioned, the spectators were tense, the court reporters were busy, and the jury was listening. This was all shown in a fairly long shot. Then was shown a close-up of a girl in the very last row. She rises and speaks—"Wait!"; back to the long shot as the whole courtroom turns to look at her. Again her close-up—"I committed that crime!" Then the long shot—spectators mill about—lawyers are puzzled—reporters run for phones—and the judge raps for order. Now if this scene consisted of a close shot of the accused being questioned—a close shot of the spectators—a close shot of the jury listening—a close shot of the court reporters working away—a close shot of the girl in the back row rising—she would then be merely one of a series of close shots and would not have an important spot in the film for the delivery of her speech.

With regard to camera movements—pans, dolly, zoom shots, *etc.*, I do not know why most of these are used, as they can only slow up the action. For instance, the scene showing a character entering a room, crossing to the opposite side, when made with a dolly, has to follow the character every foot of the way, and is naturally quite dull. Without a dolly, the director would set the camera shooting at the door. The character would enter, close the door, and step out of the picture. Now the camera would be set up at the opposite side of the room, and the character would enter and go on with the scene. This would eliminate the long walk, and would speed up whatever action there was. There are cases where the long walk might add a dramatic note to the scene, but this is very seldom. Travelling shots are important when you want to see what is happening to the stagecoach and the Indians.

Matching the action between the long shot and the closer shot is a hangover from the old silent days. In those days, a director would have, for instance, a young man walk to the piano, begin to sit down,



throw out his coat-tails from under him. While that was happening, the best cutters usually would cut to a closer angle, while the tails of the coat were still in mid-air. This was supposed to be the last word in smooth cutting. Nowadays, the best pictures are never made that way. A film cutter will complete whatever action he has to get over with one cut, then go on to the next cut, and finish that bit of action. He should never change a cut in the middle of a piece of business. It disturbs, rather than helps, the smoothness.

Now comes editing. This is as different from cutting as newspaper reporting is from news editing. The news reporter can write three columns of words about a family being evicted from their home, and it might be very good writing. The editor can get the same story with all its values in half a column.

So with the film editor. A director often spends months shooting a picture, and weeks cutting it. Then he previews it. In reel 2, the audience starts to yawn, and in reel 3 they are practically asleep. Then in the next reel, they suddenly pay attention to what's happening, and actually stay awake for the rest of the picture.

If such a situation happened in a news story, the editor would cut out the dull places—drop the repetition, and fit the good parts smoothly together, keeping the story moving, interesting and crisp. That is the job of the film editor. The only trouble is that the job is so interesting that the whole executive force, from the President right on down, suddenly become film editors, and too many cooks spoil the broth. Some executives are beginning to recognize the importance of film editing. No one knows when they will get around to understanding the sound-track.

*(At the end of the presentation a reel of film was projected demonstrating the technics of cutting for dramatic effect and shock, and cutting to rythm or tempo.)*

## CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

*The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington. D. C.*

### American Cinematographer

21 (December, 1940), No. 12

Simplifying Makeup for Motion Pictures (pp. 549-570)

W. D. FERGUSON

### British Journal of Photography

87 (October 18, 1940), No. 4198

Progress in Colour (pp. 507-508)

87 (October 25, 1940), No. 4199

Progress in Colour (pp. 515-517)

87 (November 8, 1940), No. 4201

Progress in Colour (pp. 539-540)

### Educational Screen

19 (November, 1940), No. 9

Motion Pictures—Not for Theaters (pp. 379-381, 402), Pt. 21

A. E. KROWS

### Electronics and Television and Short-Wave World

13 (November, 1940), No. 153

Columbia Colour Television, First Details of an Entirely New System (pp. 488-490)

### International Photographer

12 (December, 1940), No. 11

Process Technique (pp. 8-9, 23)

pH Control (pp. 16-17, 19)

D. K. ALLISON

### International Projectionist

15 (October, 1940), No. 10

Amplifier Power Output Data (pp. 7-8, 11)

An Instrument for Trouble-Shooting in Audio

R. J. KOWALSKI

C. E. MERVINE

Amplifiers (pp. 13-14, 16-18, 24-25)

**Kinotechnik**

22 (February, 1940), No. 2

Der neue Askania-Zeittraffer (The New Askania Time-lapse Camera) (pp. 15-17)

A. JOTZOFF

Der Beck-Lichtbogen in der Kinoprojektion (The Beck Arc for Motion Picture Projection) (pp. 18-19)

F. PATZELT

Neuzeitliche Aufnahme- und Wiedergabe-Objektive hoher Leistung (Recent High-Power Taking and Projecting Lenses) (pp. 19-20)

K. KIRCHHOFF AND P. SCHAFFER

Neue Schmalfilm-Geräte von Zeiss Ikon (New Zeiss Ikon Substandard Film Apparatus) (pp. 20-21)

Der neue Schmalfilmzeitdehner mit Linsenscheibe des Institutes für Kleinzeitforschung (New Substandard Film High-Speed Camera with Lens Disk from the Institute for High-Speed Investigation) (pp. 22-23)

R. THUN

Kandem-Stufenlinsenaufheller mit Hochintensitäts-Bogenlampe für Filmbeleuchtung (Kandem Spot Light with High-Intensity Arc Lamp) (pp. 23-24)

KÖRTING &amp; MATHIESEN, A. G.

Neue Tongilmgeräte (New Sound Film Apparatus) (p. 25)

22 (March, 1940), No. 3

Ein Spaltphotometer für Netzanschluss in Differentialschaltung (A Slit Photometer for Connection in a Differential Circuit) (pp. 31-33)

K. WERNICK

Material- und Arbeitersparnis durch und bei Kombinationsaufnahmen (Economies in Time and Materials by and with Combination Exposures) (pp. 33-36)

J. BALTZER

Die neue Koffer-Apparatur Bauer Sonolux II (New Portable Projector, the Bauer Sonolux II) (pp. 36-38)

Die Geyer-Film-Entwicklungsmaschine Nr. 187 der Geyer-Werke (The Geyer Film Developing Machine, No. 187) (pp. 39-41)

22 (May, 1940), No. 5

Aus den Anfängen der Deutschen Kinotechnischen Gesellschaft (The Start of the German-Motion Picture Society) (pp. 59-63)

J. ROLLE

20 Jahre Deutsche Kinotechnische Gesellschaft (Twenty Years of the German Motion Picture Society) (pp. 63-65)

W. RAHNS



- Entwicklungsrichtungen auf dem Gebiet der Ton-  
schriftarten (Tendencies in the Field of Sound  
Recording) (pp. 65-67) H. WARNCKE
- Übersicht über den Stand des Problems; Vergleich  
zwischen Zacken- und Sprossenschrift (Synop-  
sis of the Problem: Comparison between Vari-  
able Area and Variable Density Recording) (pp.  
67-68) M. ULNER
- Der Beleuchtungsmesser Collux (Collux Exposure  
Meter) (pp. 70-72) A. KOCHS  
22 (June, 1940), No. 6
- Die Grundlagen der Schnurschrift und neue Ver-  
fahren zu ihrer Herstellung (Fundamentals of  
Squeeze Track, and New Methods for Its Produc-  
tion) (pp. 76-81) A. NARATH, K. SCHWARZ,  
AND M. ULMER
- Ein neues Prüfverfahren für die Herstellung von  
Zackenfilmkopien (New Test Method of Variable  
Area Duplicates) (pp. 84-85) A. NARATH, AND H.  
WARNCKE
- Kraftantreib für Zeitdehnernaufnahmen (Power  
Drive for High-Speed Exposures) (pp. 86-87) H. LINKE  
22 (July, 1940), No. 7
- Neuere Versuche mit Beck-Kohlen (New Investiga-  
tions with Beck Carbons) (pp. 91-95) F. PATZELT
- Die Grundlagen der Schnurschrift und neue Verfah-  
ren zu ihrer Herstellung (Fundamentals of  
Squeeze Tracks, and New Methods for Its Pro-  
duction) (pp. 96-100) A. NARATH,  
K. SCHWARZ AND  
M. ULMER  
22 (August, 1940), No. 8
- Zuer Frage des gleichförmigen Laufes von Tontra-  
gern (The Question of Uniform Running of the  
Sound Film Track) (pp. 108-112) H. MULLER
- Ueber den Lichtstrom der Ton-Optiken (Light  
Flux in Sound Optics) (pp. 112-115) H. TUMMEL
- Der Serien-Apparat von Ottomar Anschütz (Otto-  
mar Anschütz's Series Camera) (pp. 115-116) G. ANSCHUTZ  
22 (September, 1940), No. 9
- Die Bildwandumgrenzung im Kinotheater (Screen  
Dimensions in Motion Picture Theater) (pp.  
124-26) H. JOACHIM AND A. MERZ
- Über Lampen mit nicht rotierenden Beckkohlen  
für Stromstärken über 100 Ampere (Lamps with  
Non-Rotating Beck Carbons for Currents Ex-  
ceeding 100 Amperes) (pp. 126-128) H. SCHERING

Zur Frage des gleichförmigen Laufes von Tontra-  
gen (Question of Uniform Running of Sound Film  
Track) (pp. 128-131)

H. MÜLLER

**Motion Picture Herald (Better Theaters Section)**

141 (November 16, 1940), No. 7

"Fantasia" Sound: Its Processes and Their Portent  
(pp. 7-8, 21)

"Black Light" Grows as a Source of Theater Charm  
(pp. 11-13)

**Phillips Technical Review**

5 (April, 1940), No. 4

Stereophonic Sound Reproduction (pp. 107-114)

K. DEBOER

**Photographische Industrie**

38 (April 24, 1940), No. 17

Zur Helligkeitsmessung in der Kinematographie und  
Projektionstechnik (Measurejent of Brightness in  
Motion Picture and Still Projection) (pp. 275-276)

P. HATSCHKE

## SOCIETY ANNOUNCEMENTS

### 1941 SPRING CONVENTION ROCHESTER, N. Y. MAY 5th-8th, INCLUSIVE

The 1941 Spring Convention will be held at Rochester, N. Y., with headquarters at the Sagamore Hotel. An especially interesting program of papers and presentations is being arranged by the Papers Committee, and Tentative Programs will be mailed to the membership of the Society about April 1st. In addition to the usual program of symposiums and technical papers, a special presentation and demonstration of stereophonic recording and reproduction is being arranged, to be held at the Eastman Theater in Rochester. Details will be announced later.

Early in March, hotel reservation cards will be mailed to the membership of the Society in order that accommodations at the Hotel may be reserved in advance. Members should not delay in returning these reservation cards.

### ATLANTIC COAST SECTION

On December 18, 1940, the final meeting of the year was held at the Hotel Pennsylvania, New York. Three presentations of the Hollywood Convention, held last October, were re-presented here, namely:

"The Twentieth Century Camera and Accessories;" D. B. Clark and G. Laube, Twentieth Century-Fox Film Corp., Hollywood, Calif.

"Production-Quality Sound with Single-System Portable Equipment;" D. Y. Bradshaw, *March of Time*, New York, N. Y.

"A Molded Plastic Screen with Contoured Surface;" R. O. Walker, Walker-American Corp., St. Louis, Mo.

The first presentation was notable in respect to the fact that the authors had recorded their complete presentation upon 35-mm sound-film and shown in pictures all the details and operating mechanisms and functions of this outstanding development. The picture was introduced by Mr. Herbert Griffin.

The second paper described the equipment used by *March of Time* in the production of the feature *The Ramparts We Watch*; and the third described a new type of screen surface molded of a flexible plastic material employing a specially contoured section about the holes provided for the passage of sound.

Officers and Managers-Elect of the Section were introduced and a brief account was given by Mr. R. O. Strock, the Chairman-Elect, of the program contemplated for the coming season.

### MID-WEST SECTION

At a meeting held on November 12th in the meeting rooms of the Western Society of Engineers in Chicago, a paper was presented on the general subject of



"Television" by Messrs. W. C. Eddy, Television Director, and A. H. Brolly, Chief Engineer of Balaban & Katz Corporation, Television Department, the engineers in charge of the erection of Television transmitter *W9XBK*. A demonstration of equipment accompanied the presentation. The meeting was well attended and a lively discussion followed the presentation.

Results of the election of officers and managers of the Section for 1941 were announced, as follows:

\* J. A. Dubray, *Chairman*

\* I. Jacobsen, *Secy.-Treas.*

\*\* G. W. Colburn, *Manager*

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### PACIFIC COAST SECTION

One hundred and twenty-five members and guests of the Section attended the November 18th meeting held at the Review Room of Electrical Research Products, Inc., Hollywood. Mr. J. H. Washburn, Chief Photographer of the Lockheed Aircraft Corp., presented a paper on "The Application of Motion Pictures to Aircraft Manufacture." The paper was illustrated with 16-mm pictures of test flights of finished planes. Much interest was shown in the subject, and considerable discussion ensued.

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\* Term expires December 31, 1941.

\*\* Term expires December 31, 1942.

# JOURNAL

## OF THE SOCIETY OF

# MOTION PICTURE ENGINEERS

Volume XXXVI

February, 1941

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# JOURNAL

## OF THE SOCIETY OF

### MOTION PICTURE ENGINEERS

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**\*Term expires December 31, 1941.**

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## AMERICAN STANDARDS AND THEIR PLACE IN THE MOTION PICTURE INDUSTRY\*

J. W. McNAIR\*\*

*Summary.*—The American Standards Association is a federation of trade associations, technical societies, and departments of the Federal Government. It was organized in 1918 as a result of the country's experience during the World War, and has since served as the national clearing house for standards. Some 400 American Standards have been approved to date in a wide variety of industrial fields and in the field of industrial and public safety.

Some years ago at the request of the Society of Motion Picture Engineers, the American standards Association organized a Committee on Motion Picture Standards. This might be said to be the beginning of national standardization in the photographic field. The committee brought together, under the sponsorship of the SMPE, the Academy of Motion Picture Arts and Sciences, the Acoustical Society of America, and a wide circle of scientific, engineering, and commercial groups interested in cinematography. Some of the standards approved by the ASA through the coöperative work of these many groups have become world-wide. There are 33 standards and recommended practices now before the ASA for approval as a result of long and arduous work by the motion picture Sectional Committee.

The association is also very actively engaged in the development of national standards for photography. A draft standard for determining photographic speeds of certain types of negative materials will probably be published in a few weeks for trial and criticism.

Six years ago at the request of the Society of Motion Picture Engineers the American Standards Association organized a committee on Motion Picture Standards. This committee brought together all the leading groups that were connected with the production of motion pictures. There was the Research Council of the Academy of Motion Picture Arts and Sciences. There was the Acoustical Society of America, the Optical Society of America, the American Society of Cinematographers, the Motion Picture Producers and Distributors of America, in addition to a large number of the leading manufacturing companies, trade associations, and a department of the Federal Government.

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\* Presented at the 1940 Fall Meeting at Hollywood, Calif., received October 11, 1940.

\*\* American Standards Association, New York, N. Y.

Prior to the time that this committee was formed there had been some standardization work on items relating to cameras, to film perforations, to motion picture electrical devices, to projectors, *etc.* This early standardization work, as you know, was carried out largely by the Society of Motion Picture Engineers, and it was entirely in the field of silent pictures.

With the advent of sound film many new problems arose. More societies and trade associations were formed, not only in this country but abroad. The Society of Motion Picture Engineers was no longer the only organization doing standardization work. The standardization activities of such groups as the Academy of Motion Picture Arts and Sciences were also becoming important, and there began to be a good deal of overlap in the work of various groups. Under the circumstances it seemed advisable to combine the several sets of standards then in use into one consistent set of American Standards.

The American Standards Association is a federation of national trade associations, technical societies, and departments of the Federal Government. It was organized in 1918, as a result of the country's experience during the World War with the need for national industrial standards and for a uniform gauging practice. For twenty years industry and government groups have been using this agency to solve their technical problems. Through it some four hundred American Standards have been approved in a wide variety of industrial fields and in the field of industrial and public safety. These standards are today used throughout industry as well as by municipal, state, and Federal governments. Some six hundred organizations are taking part in the work through about three thousand representatives enrolled on ASA technical committees. The standards so approved run all the way from performance standards for domestic gas ranges to specifications for Portland cement and sizes for pipe flanges and fittings.

The American Standards Association differs materially from most organizations. First of all, being a federation of trade, technical, and governmental groups in all fields it does not represent any particular point of view. Of itself it carries on no testing activities, engages in no product research work. All this is done by the national groups and the companies who are members of the Association or who are taking part in the work. For instance, the American Petroleum Institute, the Association of American Railroads, the American Institute of Electrical Engineers, the Army and Navy Departments, are

all carrying on standardization activities as an important part of their own programs. The American Standards Association serves as a clearing-house for their activities and provides the machinery for the development of standards on an inter-industry basis. As an idea of how necessary this coördinating job can be, the power companies which make up the membership of the Edison Electric Institute purchase enormous quantities of insulated wires and cables every year. The railroads also use wire and cable, and so do the electrical contractors. If each of these groups develops separate sets of specifications for wires and cables, none of the groups gets the advantage of economies resulting from one inter-industry set of specifications. A company like the Walworth Company, a large manufacturer of valves and fittings, sells to half a dozen industries. Before the development of American Standards for flanges and fittings this company had to do most of its work on special orders. It had no way of bringing its customers together to confer on materials and sizes, even though such action was to the customers' advantage.

Unlike the standardizing bodies of most other countries, the American Standards Association is not subsidized in any way by government. It is supported entirely through memberships. Sometimes the financial support has not come in fast enough to carry through the jobs brought to it by industry, for the work has constantly had a tendency to grow faster than the membership. The Association was, however, organized by industry to do industry's standardizing jobs; and so far industry has paid the way. The Association has a Constitution and By-Laws, and definite Rules of Procedure. Beyond that, it is run by the trade associations and other national groups that make up the primary membership and that are represented on the two governing bodies of the Association.

Without going too deeply into the details of how an American Standard is approved, a few words would be appropriate about American Standards Association methods. One basic principle underlies all ASA work—that any group having a substantial interest in the subject matter of a standard has a right to a voice in the development of that standard. The job of the Association is to bring together manufacturers, distributors, consumers, technical specialists, and others directly concerned with the work and to provide the machinery whereby these groups, themselves, can arrive at mutually satisfactory solutions of their technical problems.

The Association of itself initiates no work. It takes up a new proj-



ect only upon request of a responsible organization or group. The project may deal with an existing standard already in general use, or it may involve the development of an entirely new standard. It may be any one of a wide variety of types—dimensional standards; specifications for materials; methods of test; performance specifications; methods of analysis; definitions of technical terms; industrial safety codes; industrial health codes; building codes; *etc.*

For flexibility, several methods are provided by which American Standards may be developed and approved. However, all are based on the democratic principle that every group having an interest in the project has a right to take part in its development, whether it holds membership in the organization or not. The term "American Standard" means approved with the assent of every group having a substantial interest in the finished job. The technical committees which work on these jobs are like miniature legislatures set up along industrial lines. It is not unusual for them to include representation of as many as forty to fifty national organizations.

Naturally, the methods just described do not result in national standards overnight. The more groups involved and the more complicated the problems the longer it takes to get results. Some standardization jobs have been completed in a few weeks. Some jobs take years. However, when a conclusion has been reached by the democratic methods outlined above, it is pretty likely to be widely accepted.

#### MOTION PICTURE STANDARDS

With any fast-growing industry the problem of when to standardize and what to standardize becomes a very important one. If the development is allowed to proceed uncontrolled, confusion is likely to arise because of the diversity of practices, designs, and dimensions that come into use. If standardization is undertaken too soon, however, or is unwisely carried out, this may also hamper the growth of the industry.

The Society of Motion Picture Engineers, which was organized in 1916, pioneered in the field of motion picture standardization. In fact, it was started with the avowed purpose of "standardization of mechanisms and practices" employed in the motion picture industry. Some of the early standards adopted by it are still in use today.

The first attempt at national standardization was made in 1928, when the Society of Motion Picture Engineers submitted some stand-

ards to the American Standards Association for approval as American Standards. These related to professional motion picture film and equipment, exclusively. There were no competing standards in the field, and by common adoption these early SMPE standards have become practically international in scope. The situation with regard to 16-mm film and equipment, however, was quite different. As you know this equipment is used educationally and industrially and for almost every amateur use. It is in the standardization of 16-mm sound-film and equipment that the value of the American Standards Association to the motion picture industry had its first real test.

Most of you know the story of the 16-mm sound-film standards—how European industrial practice placed the sound-track to the right of the film, the exact reverse of American practice. American titles or printed matter when run through a foreign projector appeared as mirror images, and, of course, the sound part of the film could not be run at all. The chief film-producing countries were about equally divided as to use of the two practices. Commercial interests on both sides were losing money when the problem was thrown into the lap of the American Standards Association. That very day a cablegram went from the ASA to the International Standards Association, and the machinery for solving the conflict was put into motion. Eighteen months later we had a world standard for 16-mm sound-film and equipment. The certainty that any films produced could be used interchangeably on any apparatus opened a world-wide market for educational and industrial films, giving increased impetus to the already thriving 16-mm sound-film industry.

The work of the motion picture committee did not end with approval of these early standards. Right now there are a number of standards and recommended practices before the ASA for approval. These deal with terminology, dimensions, *etc.*, of film and equipment, and with various principles and practices in common use throughout the industry.

#### PHOTOGRAPHY STANDARDS

A few words would be appropriate about standardization work in another field, but one so closely allied to motion pictures that it is bound to be of interest here. In 1936, the International Standards Association asked the American Standards Association to assume the secretariat for an international project in the field of photography.

This of course stimulated the development of national standards. A large and broadly representative committee of more than 50 members was formed to take charge of the work, and under it a number of sub-committees are pegging away at specific phases of the problem. The Committee already has a number of standards in draft form. One—for determining photographic speeds of certain types of negative materials—will probably be published in a few weeks. This is an important standard to the motion picture as well as to the photographic industry. It includes a definition of the quality of exposing radiation, exposure time, concept of speed, speed criterion, speed number intervals, *etc.* It will be issued for a period of trial and criticism by the photographic industry before being approved as an American Standard.

The scope of this photography project is to include every phase of picture taking except cinematography; for example, physical characteristics and dimensions of exposing equipment, sensitive materials, methods of developing and printing, methods of determining speeds of sensitive materials, *etc.* The four main objectives before the Committee are (1) to develop a system of nomenclature and terminology which will eliminate the present confusion caused by the use of the same words and phrases with different meanings; (2) to agree on dimensional standards to bring about better interchangeability; (3) to agree on uniform methods of expressing characteristics of sensitive materials; and (4) to define tests and methods of measurement which at present are not well known or not uniformly used.

In all this photographic work the ASA is tying in with the standardization activities of the Society of Motion Picture Engineers and with every other substantially organized group in the field of photography.

The whole purpose of the American Standards Association is to bring to full realization the value of standardization work carried on by members and cooperating groups. The American Gas Association, for example, has vastly increased the acceptance of gas appliances through utilization of the ASA machinery. The Association of American Railroads has saved money for its members through agreements worked out in ASA technical committees. In mechanical, electrical, mining, building, and other fields, industry has been turning more and more to standardization to save money and increase efficiency. Today national standards, in the development of which every interested group has had a part, are being recognized as an important factor in our economy.



## ASA COMMITTEE PROPOSES METHOD FOR DETERMINING SPEED OF FILM\*

M. E. RUSSELL \*\*

The American Standards Association is now publishing a proposed method for determining photographic speed of roll film, film packs, and miniature camera films. The method was drawn up by the committee on photographic standardization (Z38), whose project was discussed in a previous issue.<sup>1</sup> The method is being published for trial and criticism for a period of approximately one year, at the end of which time it will be considered for adoption as an American Standard.<sup>2</sup> If it is finally approved as an American Standard, it is expected that it may be used as a basis for recommended exposures for picture-taking and for assigning speed numbers to films.

The proposed method for measuring speed is built about the following concept:

Photographic speed is to be considered as inversely proportional to the minimum camera exposure which a negative material must receive in order that an excellent print may be made therefrom.

This concept implies that speed can be measured by making the best possible print from each of a series of negatives (negatives which differ only in the exposure they have received) and then deciding by observation the minimum negative exposure that will lead to an excellent print. Such a concept of photographic speed seems so simple and straightforward that one might wonder why it had not been adopted years ago. The answer is that the making of picture negatives and prints to determine speed is a very unwieldy process. Besides the many difficulties in obtaining negatives properly exposed using a certain type of subject and lighting, a very large number of prints must be made and their quality judged by a large panel of judges making a multitude of observations.

Numerous systems capable of laboratory control have been proposed for measuring speed during the history of photography and

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\*Reprinted from *Industrial Standardization*, Nov., 1940, p. 277.

\*\*Chairman, Sub-Committee 2 on Sensitivity to Radiant Energy, of the ASA Sectional Committee on Standardization in the Field of Photography.

several of them have enjoyed considerable popularity. Each of these systems has been designed to give results quickly and simply and with good reproducibility. Unfortunately none of them gave results which necessarily agreed with picture-taking practice. Often the discrepancy between the calculated results and those obtained by actual picture-taking was so serious that photographers used the term "practical speed" to indicate that in practice the speed would be found to differ significantly from that obtained by the laboratory method.

Since the success of any method of determining photographic speed depends upon the ability to operate it with reasonable rapidity and with a high degree of reproducibility as well as agreeing with actual picture tests, it was necessary that a laboratory method be found from which the results would be the equivalent of picture-taking. Within recent years such a method has been evolved in the field of sensitometry, and it is this method which is used in the proposed standard.<sup>3</sup> It has been found to give excellent correlation with picture-taking practice and at the same time to be a satisfactory method for laboratory manipulation.

The method consists of plotting a characteristic curve (that is, density *vs.* log exposure) of the material being tested for a particular set of exposing and developing conditions and then determining certain constants from the characteristic curve. In the making of a characteristic curve the photographic material is given a series of exposures on an instrument known as a sensitometer. In this instrument the spectral quality of the radiation and the time of exposure are made to match the average conditions in photographic practice as closely as possible. The exact shape of the curve is influenced by the type of exposure and development used, making it imperative that these conditions be exactly those for which the characteristic curve is intended to apply.

After the sensitometric strip has been exposed and processed the blackness, or density, of each of the exposed areas is measured by a densitometer. A typical characteristic curve is shown in Fig. 1.

In Fig. 1 an attempt has been made to illustrate how the sensitometric method operates. At the top of the figure is a series of prints made from the negatives shown immediately below them. A series of exposures was given so that a range from badly underexposed to very dense negatives was obtained. The best possible print was then made from each of the negatives. It will be noticed that as the

negative exposure increases the resulting print quality increases rapidly to a high value and then remains substantially constant for further increase in negative exposure. The speed of the material is determined from the negative exposure required to yield the first excellent print.

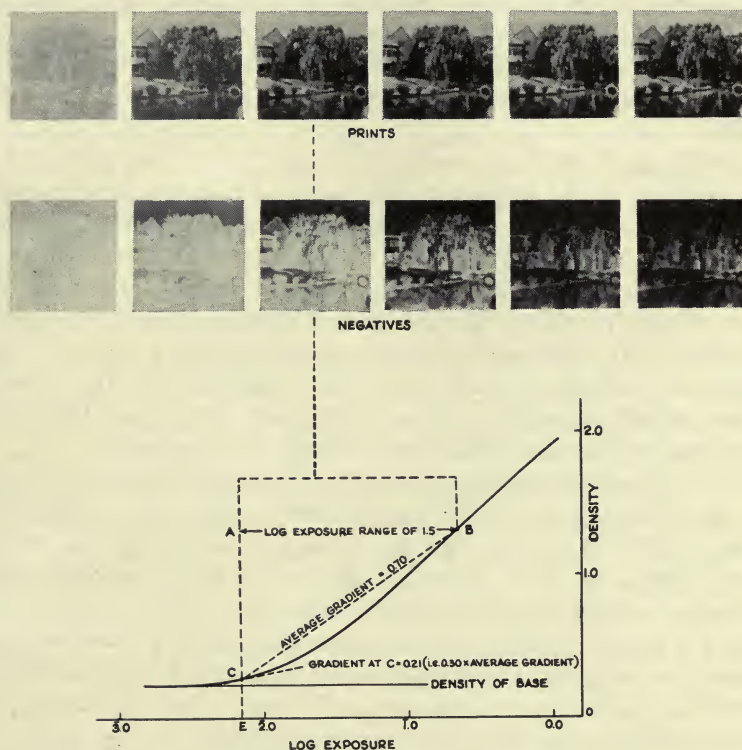


FIG. 1. Illustrating the use of the sensitometric criterion for determining photographic speeds.

The characteristic curve for the negative material used is shown in the lower portion of the figure. The slope, or gradient, of the curve at any given point indicates the rate of growth of density with change in log exposure and thus shows the difference in photographic effects resulting from a given difference in scene brightness. It will be seen that the gradient produced by the photographic material differs with the exposure.



In the illustration the negative which produced the first excellent print was so exposed that it used the portion of the characteristic curve indicated between the log exposure values *A* and *B*. The average contrast of the negative is indicated by the slope of a line drawn from the lightest to the densest part of the negative, which in this case is the line *CB*. Since the characteristic curve does not have a straight line throughout the range of densities covered by the negative, the gradient varies from one part of the negative to another, the lowest value being in the shadow region of the picture as indicated at *C*.

It has been found, as a result of a comprehensive research, that if the gradient in the deepest shadow portion is 0.30 of the average gradient for the entire negative, the negative is capable of yielding an excellent print. If the gradient for the deepest shadow is less than 0.30 of the average gradient of the negative, inferior prints will result. Thus it is evident that the concept of speed, namely, that speed is related to the minimum exposure required to give a negative from which an excellent print can be made, is equivalent to the sensitometric criterion that the gradient for the darkest portion of the subject shall be 0.30 times the average gradient of the negative.

This method of determining speed has been substantiated not only by the statistical fact that sensitometric results agree excellently with those found by actual picture-taking practice but by theoretical considerations as well. Since the quality of a photographic print depends upon the manner in which brightness differences have been recorded by the negative and the print materials, it is clear that any method for properly evaluating speed must be based upon the ability of the material to record brightness differences. The new method, in laying emphasis on the gradient characteristics of a material, is distinctly superior to the previously used methods for determining speed.

As mentioned before, the shape of the characteristic curve is dependent upon the exposing and processing conditions used. The light-source used is that adopted by the International Congress of Photography in 1928, and consists of an incandescent lamp filament operated at a color-temperature of 2360°K and screened by use of a specified liquid filter to give radiant energy of a quality closely approximating that of mean noon sunlight.

The development of roll films and film packs is carried out in a metol-hydroquinone developer approximating that used in photo-

finishing houses of the United States. The developer specified for the miniature camera films is a slower-acting developer and is widely used in the processing of miniature camera negatives.

For testing purposes the developer agitation must be equivalent to that obtained by a hand-agitated Dewar flask fitted with a device for holding the exposed sensitometric strip. All materials are developed to a specified value of average gradient rather than for a fixed time.

The present publication deals only with a method of determining speed of a specific sample of photographic material. As yet the details have not been worked out for applying the method to assigning a speed number to a product as a whole. The latter phase of the problem is being considered and no doubt some recommendation will soon be available.

Another important phase of the speed problem is the determination of recommended exposures for normal picture-taking practice. It is clear that the present specifications are not quite adequate for this problem since they indicate the minimum exposure required for excellent results only for a specific piece of material when used under a specific set of handling conditions. Recommended exposures must take into account variations in processing, in film sensitivity, in the measurement or estimation of scene brightness, and similar variables which cause the user to obtain slightly different effective exposures from what he expects. The average consumer must use an exposure value which includes a margin of safety such that he is assured under all conditions of at least enough exposure to produce excellent results. Such information can be used either in the form of printed exposure guides or in connection with exposure meters.

Thus far the committee has not had an opportunity to give serious consideration to the details of this problem of determining recommended "calculator numbers" or "meter setting values." It is clearly recognized, however, if the whole photographic industry is to derive maximum benefit from the standardization project, that specifications must be drawn as soon as possible to extend the method for measuring speed of a specific sample to the assigning of a speed number to a product as a whole and to the determination of recommended meter settings.

Sub-Committee No. 2 on Sensitivity to Radiant Energy, which prepared the proposed standard on photographic speed of films for consideration by the ASA committee, has the following membership.

The names of the individual members are followed by the organizations they represent on the sectional committee.

M. E. RUSSELL, Eastman Kodak Company, <i>Chairman</i>	S. McK. GRAY, Electrical Testing Laboratories
PAUL ARNOLD, Agfa Ansco Division of General Aniline and Film Corporation	ALBERT F. HOGLE, Master Photo Finishers of America; The Photo Finishing Institute
WALTER CLARK, American Committee of the International Congress of Photography, and Eastman Kodak Company	F. K. McCUNE, National Electrical Manufacturers Association
RAYMOND DAVIS, National Bureau of Standards, U. S. Department of Commerce	BRIAN O'BRIEN, Optical Society of America
HANS DESSAUER, The Haloid Company	ROWLAND S. POTTER, Defender Photo Supply Company, Inc.
W. N. GOODWIN, JR., National Electrical Manufacturers Association	E. D. TILLYER, American Optical Company
	D. R. WHITE, duPont Film Manufacturing Corporation

Other sub-committees are now at work on the program of the ASA Committee on Standardization in the Field of Photography (Z38) as follows:

Physical dimensions of sensitive materials, specifically of unexposed, unprocessed sensitive materials and holders therefor (Sub-Committee 1)  
 Supports for sensitive coatings (Sub-Committee 3)  
 Exposing equipment: cameras, lenses, shutters, etc. (Sub-Committee 4)  
 Photographic characteristics of illuminants (Sub-Committee 5)  
 Processing equipment (Sub-Committee 6)  
 Printing and projection equipment (Sub-Committee 7)  
 Processing (Sub-Committee 8)  
 Definitions; abbreviations and symbols; form and arrangement of published standards; numbering of standards (Sub-Committee 9)

The Optical Society of America has the administrative leadership for the work of the ASA committee, with Loyd A. Jones as chairman, and J. W. McNair of the American Standards Association as secretary.

#### REFERENCES

- <sup>1</sup> McNAIR, J. W.: "Progress Made in Photographic Standardization," *Industrial Standardization*, **X** (Dec., 1939), p. 293.
  - <sup>2</sup> These proposed standard specifications will be printed in the *J. Opt. Soc. Amer.* (Jan., 1941).
  - <sup>3</sup> JONES, L. A.: "The Evaluation of Negative Film Speeds in Terms of Print Quality," *J. Franklin Inst.*, **227** (1939), p. 497.
- JONES, L. A., AND NELSON, C. N.: "A Study of Various Sensitometric Criteria of Negative Film Speeds," *J. Opt. Soc. Amer.*, **XXX** (Mar., 1940), p. 93.



## OPERATION OF THE VARIABLE-INTENSITY RECORDING SYSTEM\*

C. W. FAULKNER\*\* AND C. N. BATSEL†

**Summary.**—A description of the system is given with line drawings illustrating the optical design together with operational characteristics of the system and an account of how it has been adapted to existing studio technic.

The stage channels, which are all mobile, are described with illustrations, and methods of setting the channels up for operations are discussed.

The RCA variable-intensity recording system was put into use at Twentieth Century-Fox Studios in November, 1938. Standard Class A track, 100 mils in width, is used for all dialog and release negatives and Class A push-pull single-width track is used for music scoring original negatives.

Fig. 1 is a diagram of the optical system and shows the positions of the lamp *A*, galvanometer *F*, and the penumbra mask *T*. The lens *B* is a condenser lens and in combination with lens *E* forms an image of the lamp filament *A* on the galvanometer mirror. A portion of the recording light-beam at the slit is reflected by the lens mirror *L* back through the monitor system onto the monitor card. The lens *G* just back of the slit *H* forms an image of the galvanometer mirror in the objective lens *J* which images the slit *H* onto the film at an optical reduction that gives a recording light-beam  $\frac{1}{2}$  mil in height and any length up to 100 mils. *V* is the noise-reduction motor that actuates the moving penumbra mask *U* which is located a few thousandths of an inch back of the fixed penumbra mask. *W* is a selective mirror which diverts light from the recording light-beam downward through the cylindrical lens *X* onto the second mirror *Y* out through the splitting lens combination *Z* to the photocell *Q*. The system is designed with the splitting lenses so that it may be used with push-pull systems. The desired noise-reduction is ob-

\* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received November 4, 1940.

\*\* Twentieth Century-Fox Film Corp., Hollywood, Calif.

† RCA Manufacturing Co., Hollywood, Calif.

tained by mechanically adjusting the movable penumbra mask into the light-beam until the intensity of the light at the slit is reduced to its correct value. It is pulled down by the noise-reduction current a distance proportional in amplitude to the signal plus the desired margin.<sup>1</sup>

Fig. 2 is a photograph of the optical system with the photocell cover removed, showing the relative positions of the cell and splitting lenses.

In installing the system in the studio it was desirable that as few operating changes as possible be made so as to reduce confusion. The motor system and operational features were kept as nearly stand-

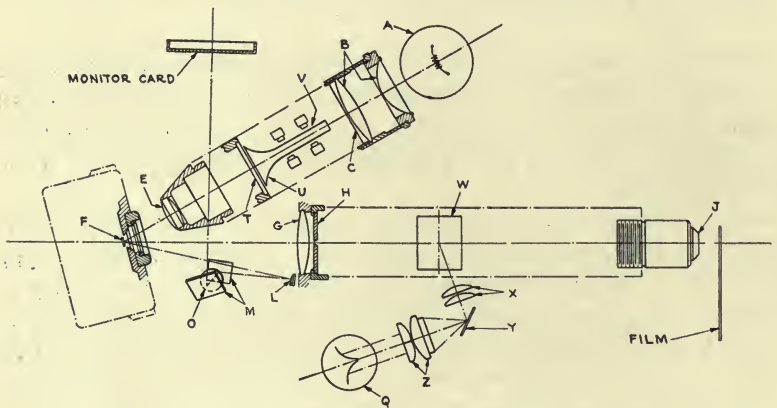


FIG. 1. Optical system.

ard as possible with existing studio equipment. Sufficient tests were run to determine the exposure range and the linear modulation range of the system in order to adapt it to the existing processing conditions of the laboratory.

The system has a linear exposure from no light to full intensity, the upper limit being determined by the intensity of the source, which in turn is limited by the maximum safe lamp current. Fig. 3 is a curve showing the linearity of exposure light *vs.* deflection of the galvanometer from zero (no light) to 100 per cent modulation of the system (full light).

Fig. 4 is a curve showing the input *vs.* output from the system and the distortion present.

This system, making use of a constant-width aperture, has distinct advantages over the variable aperture in that distortion from film travel, and other distortions commonly associated with a variable aperture are considerably reduced. Also, the constant-width slit permits better control of frequency equalization of the recording channel as there is no variation in film response with amplitude of signal at the higher frequencies.

Fig. 5, curve *A*, is the electrical response of the system. Curve *B* is the response of the system through the PEC monitor, curve *C* is the overall recording characteristic including the galvanometer, and curve *D* is the response from the film measured through a sound-head which has been equalized for flat response from the SMPE test reel.

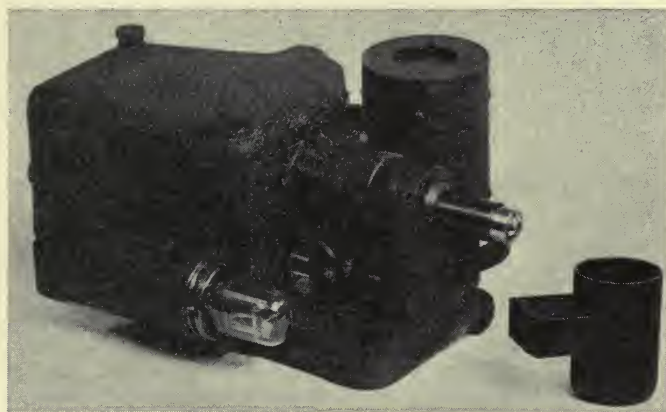


FIG. 2. Optical system with photocell cover removed.

To utilize more fully the advantages offered by this system it was felt advisable to start from a point sufficiently low on the penumbra curve in order that the system could accommodate a higher signal level.

Fig. 6 is a typical track gamma curve, density *vs.* galvanometer or penumbra deflection developed to a gamma of 0.40. Hence for 100 per cent deflection of the penumbra the mean density is approximately 0.7, represented by point *A*. This represents the center-point of the penumbra where the moving vane passes behind the fixed vane. Modulation about this point therefore represents maximum with the light modulating from zero to maximum and the density modulating from its lowest value up to 0.83.



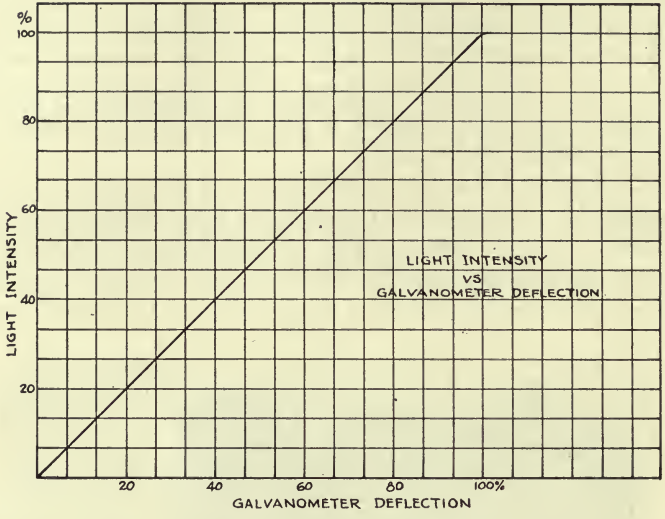


FIG. 3. Exposure light vs. deflection of galvanometer from zero to 100 per cent modulation.

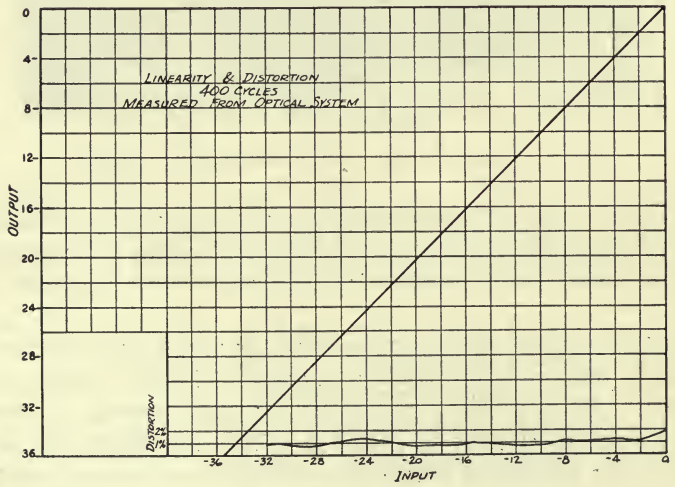


FIG. 4. Curve of input vs. output of the system,

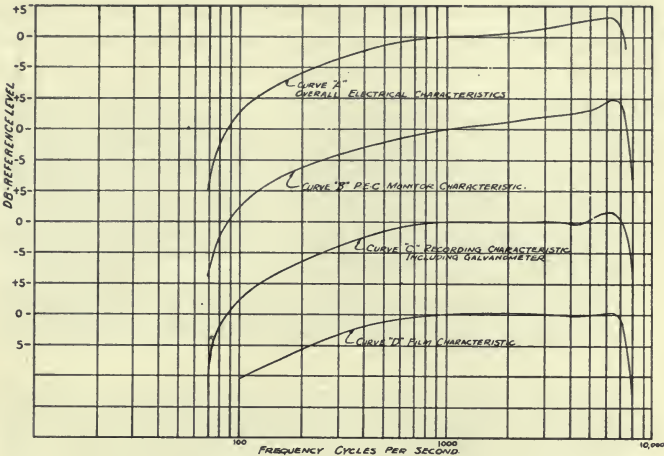


FIG. 5. Electrical response.

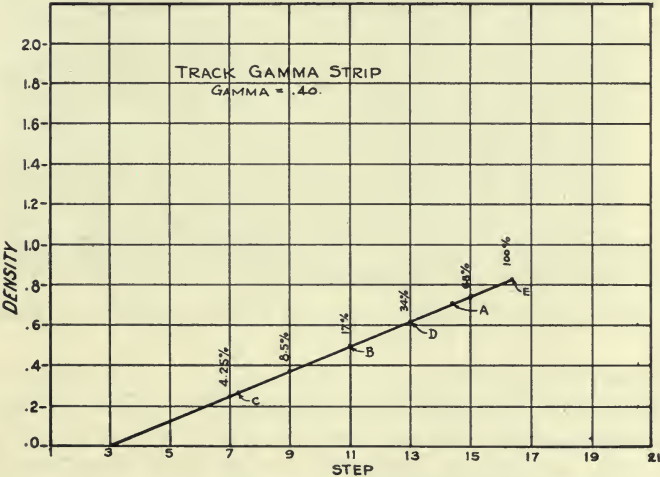


FIG. 6. Typical track gamma curve.

In order to conform to present laboratory practice, it was deemed desirable to keep the unbiased negative density at 0.5. This density is obtained at 17 per cent of the penumbra range and is represented at point *B* on the curve. The noise-reduction is taken at a point *C*, which is 10 db below *B*, and is obtained at 5.4 per cent of the penumbra range.

In practice the moving penumbra vane is mechanically set at point *C* for no modulation. The application of sufficient signal carries the vane up to point *B*, which represents 100 per cent recording level or a modulation range from 0.3 to 0.65 in density. Signals

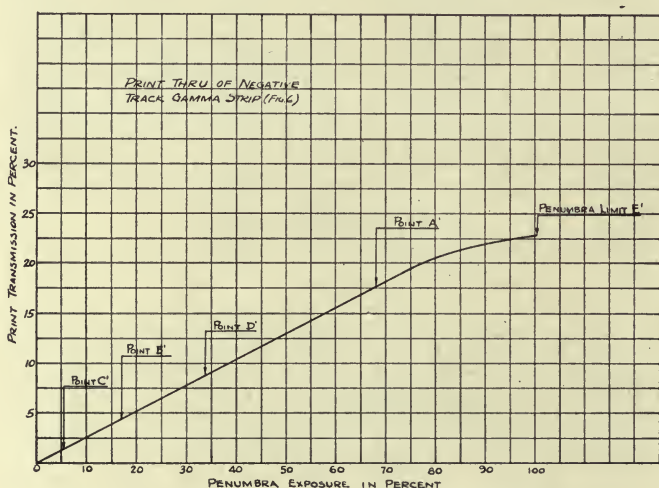


FIG. 7. Curve of strip printed from sample of Fig. 6.

that carry the vane up to 0.7 represent peaks and unusually loud sounds which produce a maximum density of 0.83 on the negative. The negative range *A* to *B* is utilized in this manner for peak protection.

A printed strip of Fig. 6 is shown on Fig. 7. This shows a print linearity up to 80 per cent of the penumbra range. The relationship of the points on the track gamma strip correspond to similar points on the print transmission curve. The region *C'* to *D'* represents the 100 per cent recording range on the negative. *D'* to *E'* represents the portion of the negative from *D* to *E* and is reserved for overloads.

All stage recording is done by mobile units. The trucks are two-ton Fords with special bodies designed to meet the requirements of



the studio (Fig. 8). The recording equipment is mounted in a compartment occupying the center portion of the truck body (Fig. 9). The rear portion of the body contains all the power equipment, selsyn master motor and storage space for the stage mixer and cables. The

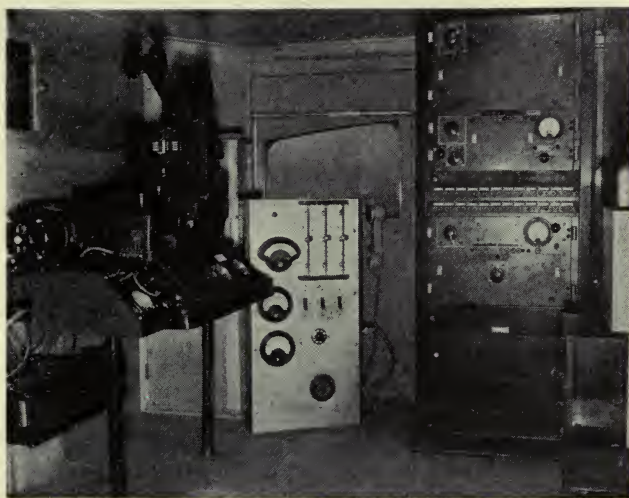
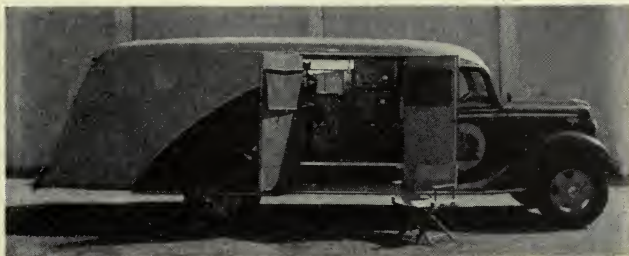


FIG. 8. (*Upper*) Exterior of mobile unit.

FIG. 9. (*Lower*) Recording equipment in mobile unit.

units are all a-c operated with standby *A* and *B* battery complement. They carry no power supply for the motor system, use being made of 220-volt mains wherever they are available. In the event that location work necessitates auxiliary power, a Dodge  $\frac{3}{4}$ -ton truck is used. In this truck are mounted (Fig. 10) batteries and a motor-driven alternator of sufficient capacity to furnish 220-volt 3-phase power to operate the recording truck. A charging generator driven by the

truck engine may be used either to float the batteries or charge them during idle periods, thereby avoiding the necessity of recharging from power mains.

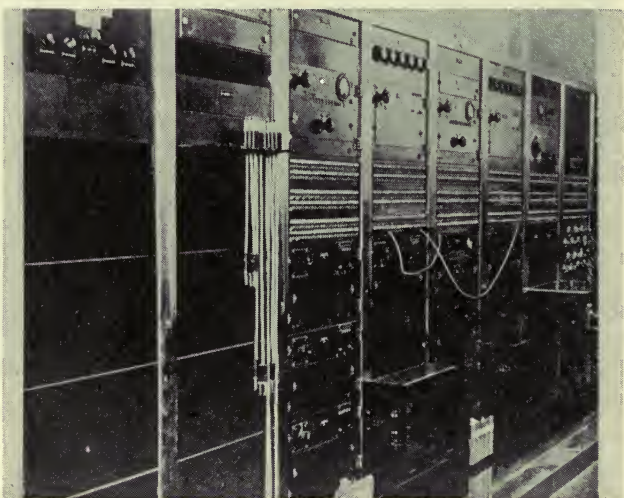
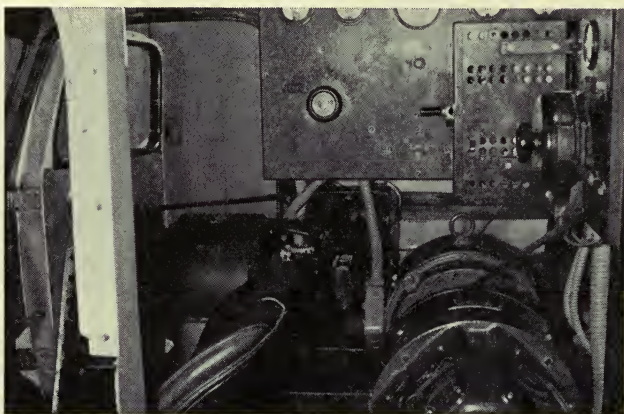


FIG. 10. (*Upper*) Power supply in mobile unit.  
FIG. 11. (*Lower*) Re-recording and scoring amplifier installation.

The audio channel equipment comprises a four-position mixer containing four two-stage microphone amplifiers which, with the microphone and boom equipment, constitutes the equipment normally

used on the set proper. Transmission from the mixer is through a 90-Hi-78 high-pass and an 8000-cycle low-pass filter into the main gain amplifier which drives the modulator. The fixed dialog equalization is located in this amplifier. The noise-reduction amplifier is bridged off the bridging bus through a 5000 to 500-ohm pad. The monitoring amplifier is bridged across the main amplifier interstage for direct monitoring. The volume indicator is also bridged across the main amplifier output.

The output of the PEC monitoring photocell is transformed and fed into the PEC voltage amplifier. Provision is made for automatically switching the output of this amplifier to the input of the monitoring amplifier during takes so that both truck and mixer monitoring is normally PEC. The mixer may listen to direct monitoring during takes by switching to the bridging bus by means of an *AB* key at the console.

The recorders, which are of the magnetically driven drum type, are equipped with the visual monitoring card which is of considerable aid to the operators in checking levels, setting up, and observing the operation of the modulator system in general. Operating experience, however, has proved the desirability of having a reliable means of actually measuring the transmission of light through the recording slit. It is particularly important that the operator be able to check the biased and unbiased position of the shutter in respect to the mid-point position of the galvanometer. To accomplish this the recorders are now being equipped with a light-meter.<sup>2</sup>

This device is based on the principle of applying a fixed alternating voltage to the d-c polarizing voltage of the photocell. The output of the photocell is amplified through the PEC amplifier system whose output is read in terms of db on an ordinary power-level indicating meter. A variable attenuator between the amplifier and the meter is provided with steps that represent the output from the cell with 100 per cent light, 50 per cent light, and from this point on down there are twenty steps of one db each. This arrangement permits the operator quickly to check his 100-per cent and 50-per cent illumination points.

The final noise-reduction shutter position is then obtained by adjusting the zero shutter current until the output meter reads the required level in db below the 50-per cent point. At present, with the use of 10-db reverse bias, this setting is 20 db below 50 per cent.

Synchronizing marks and sound-track slates are photographed on



the film in the sound-track area while the machine is at rest. This procedure is possible since all motors are selsyn interlock.

The re-recording and scoring amplifier installation is shown in Fig. 11. All amplifier equipment is the same as that used on the trucks. It is arranged in the rack, however, best to serve the needs of the plant and will accommodate simultaneously scoring and re-recording operations. The scoring mixing console is arranged so that, by patching, the two four-position mixers may be fed into separate channels for dual recordings.

The re-recording channel reproducing complement consists of ten film reproducers, nine of which are dummies employing the RCA rotary stabilizers and one is a magnetically driven drum film-phonograph. They are all equipped for push-pull or standard reproduction. The PEC monitoring is supplied as in the mobile units and may be switched from direct to PEC at the mixing console as desired.

The recorders are the same as the mobile units with the exception of the push-pull music scoring machine. The optics of this machine are different from those of the standard RCA variable-intensity in that a double penumbra is formed at the slit. These operate 180 degrees out of phase and are separated by a septum so that the two tracks do not overlap.

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<sup>1</sup> DIMMICK, G. L.: "The RCA Recording System and Its Adaptation to Various Types of Sound-Track," *J. Soc. Mot. Pict. Eng.*, **XXIX** (Sept., 1937), p. 258.

DIMMICK, G. L.: "Optical Control of Wave-Shape and Amplitude Characteristics in Variable-Density Recording," *J. Soc. Mot. Pict. Eng.*, **XXXIII** (Dec., 1939), p. 650.

<sup>2</sup> DAILY, C. R.: "Use of an A-C Polarized Photoelectric Cell for Light-Valve Bias Current Determination," *J. Soc. Mot. Pict. Eng.*, **XXXIII** (Oct., 1939), p. 394.

#### DISCUSSION

MR. LORANCE: What are the slit image dimensions on the film?

MR. BATSEL:  $\frac{1}{2}$  mil high by 100 long.

MR. LORANCE: What is the lamp current, and what type of lamp is necessary?

MR. BATSEL: We use a bayonet base T-8 bulb curved filament recording lamp rated at 10 volts, 7.8 amperes. The lamp current is at present about 7 amperes.

MR. LORANCE: That is on the usual standard negative emulsions?

MR. BATSEL: Yes, the system is operated so that 17 per cent of the total exposure produces the unbiased negative density.

DR. FRAYNE: Is it possible to expose 1301 emulsion with this type of optic?

MR. BATSEL: We can expose 1301 stock. If developed at present gammas it would require about 0.4 ampere increase in lamp current, which would still leave a safe margin with the 7.8-ampere lamp; or we could expose the unbiased negative density at a higher point than 17 per cent of the exposure range and work with lower lamp current.

MR. RYDER: Is sufficient exposure available for the proper exposing of either the 222 or the 1302 fine-grain film?

MR. DIMMICK: If a high-pressure mercury-vapor lamp is employed as a light-source, fine-grain films may be exposed without difficulty at normal negative gamma. If the negative gamma is increased, it is possible to expose fine-grain films with an incandescent lamp. In the latter case, an optical compensator is placed in the recording optical system to reduce the effective overall gamma to unity.

It also has the advantage that the full characteristics of the film will be compensated, at the same time giving greater depth to the recording motor.

DR. FRAYNE: I am very much interested in Mr. Dimmick's remarks about the possibility of anticipating the film distortion by putting in a counteracting distortion. We have tried such a scheme but failed because we never could tell in advance exactly what the film characteristics would be. They change from time to time, and from batch to batch of emulsion.

MR. DIMMICK: The present low-gamma variable-density system is not linear for high print transmissions. In addition, there are variations in the overall transmission curve due to normal variations in the negative and print developers. In my opinion, it is better to make the average transmission characteristic linear and accept normal variations from this condition, than it is to accept both the non-linearity and the variations.

MR. RYDER: In other words, if we have a known distortion in a given direction and compensate largely for that distortion, and then take the average around that point, we would be better off than taking the fixed amount of distortion.

MR. DIMMICK: Yes.

MR. ALBIN: Mr. Dimmick's point is good theoretically, but it does not work out in practice. If we know the average variation in film distortion and make an average correction, then part of the time there is over-correction and the distortion becomes tremendous. It is apparently far better to be under-corrected than over-corrected.

In other words, considerable compression of the type introduced by the film characteristic may be tolerated by the listener, but practically no expansion is permissible. The plan of pre-distortion, anticipating film distortion, is very admirable provided that film compression is not less than predicted and expansion results.

MR. DIMMICK: Perhaps Mr. Albin would prefer a degree of compensation that would make the transmission characteristic linear at one limit of the processing tolerance and allow it to be slightly curved in its present direction for the other limit. The overall result would still be an improvement over present practice.

MR. LORANCE: Mr. Batsel said that he used alternating current on the photo-cell in the exposure meter. Over what range is the cell linear? Are there any troubles with non-linearity?

MR. BATSEL: We are able to work the meter through a linear range of 36 to 40 db, which is sufficient for this application.

MR. LIVADARY: If I understand Mr. Dimmick correctly, the pre-distortion that may be put into the optical system of the intensity recorder is to be such as to compensate for future distortion introduced by the characteristics of the processed film, and thereby result in a linear output from the film within the modulation range of the apparatus.

In view of the strong argument that such a linear record is not desirable, as exemplified by efforts made to compress variable-area records that are inherently linear, does that mean that linear reproduction is satisfactory in variable-intensity recording, whereas it fails in the variable-area case?

MR. DIMMICK: Most of us agree that if compression is used, it should be of the type that does not produce wave-shape distortion. It would therefore seem advisable first to make the variable-density system linear and to apply non-distorting electronic compression to any extent desired.

There seems to be some misunderstanding as to how the compensation is introduced. A correcting plate can be placed in the light-beam of the system, the plate being of such shape as to make the relation of intensity to deflection logarithmic. In other words, the recording system can be given a gamma different from unity.

DR. DAILY: In determining optimal film-processing conditions, have you observed that distortion calculated from transmission measurements of printed-through IIb strips do not always provide a reliable index of the sound quality of the print?

MR. BATSEL: We prefer to use print-through strips from actual track gamma strips made on the recorder. The negatives do not show the usual shoulder observed on the H&D strips; consequently actual transmission measurements of the prints are much more indicative of recording results.

MR. ALBIN: In the curve showing the relation between negative exposure and positive transmission, which was quite linear over the usable range, how was the transmission of the positive measured—with a densitometer, measuring diffuse density; or by sound-head, measuring projected density, for example?

MR. BATSEL: Measurements are made in a standard sound-head reproducer. Transmission values are read by means of the RCA ultrasensitive d-c meter from the output of the sound-head photocell.



## GROUND-NOISE REDUCTION SYSTEMS\*

E. W. KELLOGG\*\*

**Summary.**—*This paper is not a discussion of any specific commercial ground-noise reduction system, but rather of general principles, and is an effort to formulate a statement of the desired characteristics of a ground-noise reduction system, in terms of such factors as promptness of opening, peak reading, and filtering. In this it is assumed that anticipation is not employed. It is desirable to limit the filtering to a single stage of resistance-capacity filtering (or equivalent). Slow closing helps filtering and peak reading. The better the peak-reading properties of the circuit and the less the filtering delay, the smaller can the margins be made without causing too frequent clipping.*

*A number of circuits are discussed which have been proposed for improving the filtering without sacrificing quickness of opening or reasonably rapid closing.*

*In some operations, anticipation is entirely practicable, and if this is done, it appears possible to provide an almost perfect envelope current.*

The pioneers of photographic sound recording had to solve many problems, some of which are still with us. One such chronic problem is ground-noise, due to scratches and dirt on the film. L. T. Robinson<sup>1</sup> realizing that most of the noise came from specks in the clear area of the film rather than from holes in the black areas, proposed to bias the galvanometer during periods of low modulation, so that the clear area was just enough to accommodate the modulation. He employed the simple circuit shown in Fig. 1. Recording at that time was being performed by galvanometers of the oscillograph type which had a resistance of about two ohms. In such a low-impedance circuit, it is a simple matter to employ inductances and resistances to separate the high and low-frequency components, but difficult to take advantage of condensers. The circuit used by Robinson was by no means perfect, but it demonstrated the important principle and did reduce the ground-noise.

C. W. Hewlett<sup>2</sup> and C. R. Hanna,<sup>3</sup> who were also among the first to contribute to the solution of this problem, performed their recti-

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\*Presented at the 1940 Fall Meeting at Hollywood, Calif.; received December 3, 1940.

\*\*RCA Manufacturing Co., Camden, N. J.

lying functions in the amplifier, thereby facilitating the filtering and making it possible to eliminate from the waves being recorded any distortion due to loading the circuit by the rectifiers. Figs. 2 and 3 show in simplified form the Hewlett and Hanna circuits.

In variable-width recordings of the unilateral type used prior to 1932, biasing the galvanometer puts the low modulation recording at the extreme edge of the sound-track as shown in Fig. 4. There is an objection to doing this, because the recording optical systems gave

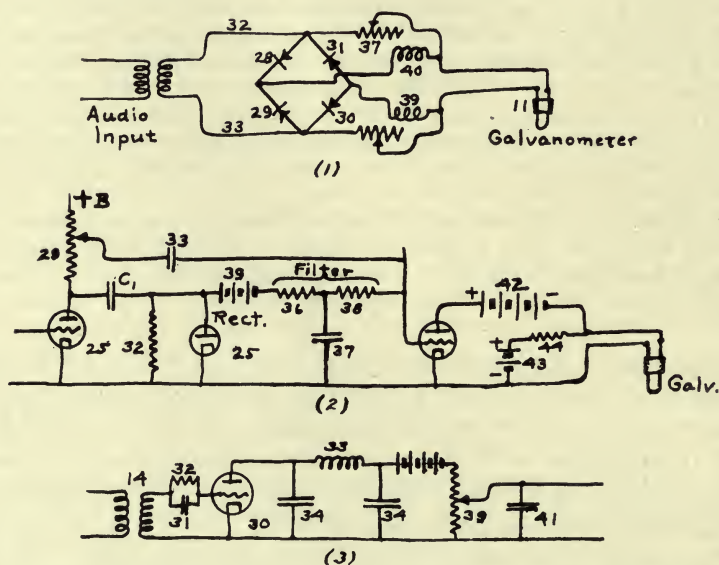


FIG. 1. Original ground-noise reduction circuit of L. T. Robinson.

FIG. 2. Circuit of C. W. Hewlett.

FIG. 3. Circuit of C. R. Hanna.

slightly poorer resolution at the edges of the track, and the reproducing optical systems, in many cases, gave poor illumination of the edges of the track. There was also danger of entirely losing some of the sound in case of sidewise weaving of the film. H. McDowell<sup>4,5</sup> corrected this fault by employing a shutter to intercept a part of the recording light-beam, instead of biasing the galvanometer. This left the small modulation at the middle of the track, the unused track area being unexposed and clear in the negative and therefore black in the positive, as illustrated in Fig. 5. The work of McDowell, supplemented by that of others,<sup>5</sup> and the successful application of the

biasing system to variable-density recording<sup>6</sup> directed the attention of the industry to the advantages to be gained from ground-noise reduction systems as applied to variable-area recording. Commercial designs of shutters<sup>7</sup> and suitable amplifiers<sup>8</sup> were made available.

The adoption of the symmetrical track<sup>9</sup> by RCA obviated the original objection to biasing the galvanometer, for in the case of the symmetrical track, biasing the galvanometer leaves the low modulation at the middle of the track (Fig. 6). Other considerations, however, resulted in a return to the use of shutters, and by suitable modifications a system employing shutters can be readily adapted to various types of recording such as push-pull track and the penumbra system of variable-density recording.<sup>11,12</sup>

There have been numerous variations in the circuits for providing the control current, generally representing slightly different points of view of those who are designing equipment or are using it, or a different emphasis on the importance of several factors. It is the purpose of this paper to review the arguments for and against a number of the actual or proposed circuits.

#### DESIRED CHARACTERISTIC OF GROUND-NOISE REDUCTION SYSTEM

In general terms, it may be said that the purpose of a ground-noise reduction system is to keep the sound-track light transmission at the lowest average value that will permit the required modulation, since any additional (unmodulated) light simply increases the noise. The changes in average transmission, however, must not be rapid enough to produce audible sounds. These statements apply equally to variable-density and variable-width systems. The *absolute* magnitude of the light modulation should not be altered by anything that the ground-noise reduction system does. Thus when it reduces the average light reaching the photocell, this light is modulated by a higher percentage by the audio waves than would otherwise be the case. In fact, we might say that the ground-noise reduction system so regulates the average light in relation to the magnitude of the recorded waves that the modulation is kept as near 100 per cent as is practicable, without running too much risk of its actually reaching 100 per cent. Since the fundamentals of ground-noise reduction as outlined above, are essentially the same in both the density and the area systems, we can discuss the ground-noise reduction requirements in terms of its application to a variable-area track, and assume that the latter is one of the type made with a shutter, such as illustrated



in Figs. 5 and 7. The axis of the sound-wave trace produced by the galvanometer vibrations is a straight line parallel to the axis of the track, and a separate trace is produced of the movements of the shutter. When the modulation is low, the shutter advances so that a very minute light-spot strikes the film, producing a narrow black line on the negative, or a narrow clear line on the print. As the modulation increases, the shutter backs away, and should do so in such a manner that it at no time prevents the recording of the complete audio waves. This condition is not entirely achieved in practice,

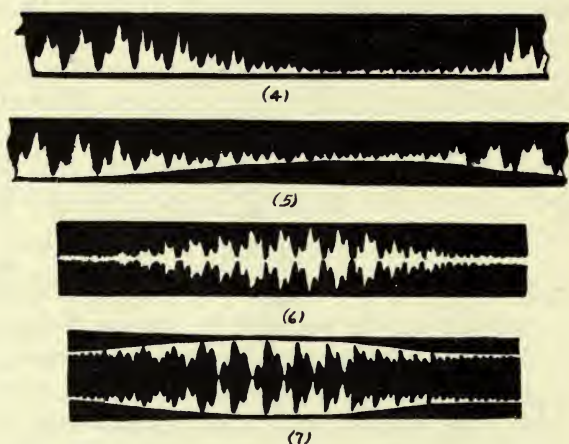


FIG. 4. Track produced by galvanometer bias;  
Robinson.

FIG. 5. Track produced by shutter; McDowell.

FIG. 6. Symmetrical track with biased galvanometer.

FIG. 7. Symmetrical track made with shutter.

and we refer to the system as “clipping” the tops of the waves. If there is not a great deal of clipping, it may be difficult to detect the effect in listening tests, but there can scarcely be any doubt that it is detrimental, and one of the principal purposes of our efforts to improve ground-noise systems is to minimize the clipping. On the other hand, we do not want the shutter to back away to an unnecessary degree, for this leaves large clear areas on the print, in which dust and film abrasions will produce noise.

The ideal characteristic of a ground-noise reduction system has been aptly described by saying that the shutter trace should follow

the "envelope" of the sound-waves. If we were given an outline of audio waves such as an enlarged recording or an oscillograph trace, there is little doubt that a large number of engineers, if asked to draw an envelope, would draw substantially the same curve, but if we attempt to define an envelope, we find that there are cases of ambiguity. We speak of the envelope trace as following along and just touching the tops of the waves, but what if some waves are higher than others? If there are two tall waves and a short one between, we should, in general, say that the envelope curve will ignore the shorter wave and touch only the higher peaks, but this will depend upon how far apart the high peaks are. Fig. 8 shows two possible envelope curves for the same audio waves. Obviously if the modulation drops, the envelope curve should follow down. It is not difficult to see when it should follow down and when not, provided we can look

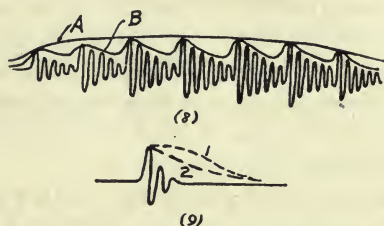


FIG. 8. Two types of envelope curve.

FIG. 9. Delayed discharge and exponential discharge curves.

at the complete recording, and see what is ahead. But if we do not know what is coming, it is not so simple a matter to decide whether a given high peak which we have just passed is the last one of a series and it is now time to begin to drop; or how rapidly can we drop without cutting the next peak (which will presumably be of lower amplitude, but whose exact amplitude we do not know). We should like to require of our ground-noise reduction amplifiers a degree of intelligence and prognostication that we do not ourselves possess. Realizing that the drawing of a logical envelope wave requires that we know what is coming, we can see that our system can be made much more satisfactory if anticipation is possible; or, in other words, if the waves can reach the ground-noise reduction system slightly in advance of their actual recording on film. Anticipation through the employment of a delay circuit is mentioned by Silent and Frayne,<sup>6</sup>

and others. Anticipation can also be more simply provided in certain cases, such, for example, as in re-recording, or in making direct positives as described in a paper by G. L. Dimmick<sup>13\*\*</sup> and in several U. S. patents of earlier date.<sup>14,15</sup> Let us, however, for the moment confine ourselves to the case where anticipation is not possible, and ask ourselves what we should like our ground-noise system to do.

After a period of little or no modulation, the arrival of any audio wave, in general, means that more waves will follow, and probably in increasing amplitude. The first wave will inevitably be clipped unless it is smaller than the shutter opening at the time. The shutter, however, should open as promptly as possible and thereby minimize the number of clipped waves. As soon as modulation of appreciable amplitude is present, it is permissible to increase the width of the clear film, for it is well recognized that more ground-noise can be tolerated when masked by modulation. Therefore, as soon as there is any evidence of audio waves to be recorded, the shutter should open far enough at least to increase the clearance to something substantially greater than the narrow zero-modulation clearance. Thereafter, the shutter should continue to open at a rate depending upon the actual magnitude of the incoming audio waves.

During a sustained train of waves, the shutter should, of course, remain open by an appropriate amount. When the waves begin to decrease in amplitude, the shutter may begin to close. It is necessary that the shutter close with sufficient rapidity so that we do not hear conspicuous ground-noise after the modulation has ceased or reached a low value. There are two factors which contribute to making moderately slow closing permissible. Reverberation both in the recorded sound and in the reproducing auditorium prevents an abrupt stop of the recorded sound, and thus masks ground-noise. There is, perhaps, also an accommodation effect by reason of which the ear is less sensitive to faint sounds immediately after a relatively loud sound.<sup>16\*</sup> It is desirable to take advantage of these factors, and not close the shutter any more rapidly than is required to keep the ground-

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\*Stevens and Davis<sup>16</sup> (*Hearing*, p. 217) discuss this under the headings "Fatigue" and "Persistence of Sensation." Experimenters do not find anything comparable with adaptation of the eye to light-intensity. Tests by Békésy are reported showing that the ear does not recognize any difference between an 800-cycle tone which ends abruptly and one which decays 60 db in 0.1 second.



noise from being noticeable. This will in turn depend somewhat upon the magnitude and type of the ground-noise. Thus the steady hiss, characteristic of density recording, appears to require quicker closing than the more haphazard noises which result from too much clear film in a variable-width track.

There are two distinct advantages in slow closing. One is that it greatly reduces the ripple which has to be removed by a stage of filtering; the second is that every time the shutter closes there is danger of clipping waves the next time it has to open. Thus, it would be unfortunate for the shutter to close if it would have to open again immediately afterward for new high modulation. If the shutter starts to close immediately after the passage of a peak in the audio waves, it will attempt to follow the individual audio waves, especially if these are of comparatively low frequency. Such movements of the shutter are obviously not a part of the desired envelope characteristic, which should follow straight across from top to top of the waves. It would appear logical, then, to ask that the shutter remain substantially at the full opening called for by the magnitude of the last peak, for a period corresponding to one cycle of the fundamental audio wave. If after this interval another wave of equal magnitude fails to arrive, the shutter may begin cautiously to close. It would call for unjustifiable complication to specify that our shutter should adopt a different period of expectant waiting, depending on the frequency of the tone being recorded. We shall therefore specify a substantially fixed time which will cover the fundamental period of most audio tones to be recorded. Since voice is the most important of the audio tones and only exceptionally do men's voices drop much below 100 cycles, it might be in order to specify a waiting period of the order of ten milliseconds as desirable. Thus a closing characteristic after modulation has stopped, as illustrated by curve 1 of Fig. 9, would be desirable rather than the one indicated by curve 2 of the same figure. It is, of course, not important as a practical matter that conditions remain absolutely static for the suggested ten milliseconds, and curve 1 has been drawn to represent a recovery or closing that is not perfectly flat, but relatively slow for the first ten milliseconds. The filter, which is a part of every ground-noise reduction system, can easily be made to give a closing characteristic approximating the shape shown by curve 1, but for reasons which will be explained, the hesitation of the discharge must be produced otherwise than in the filter.

## FULL-WAVE VS. HALF-WAVE RECTIFICATION

Current for operating a shutter or biasing a galvanometer has in all ground-noise reduction systems been derived from a rectifier supplied with audio-frequency voltage. There are many types and designs of rectifiers and their performance is by no means equivalent. One of the first questions which comes up is the desirability of using a full-wave rectifier. The case for half-wave rectification has been well put by S. Read, Jr.<sup>17\*\*</sup> In the first place, it is only the peaks in one direction which the shutter has to clear. If the peaks of the opposite polarity are smaller, their inclusion in the rectifier will not affect the rectified voltage, whereas if they are larger, they will cause the shutter to open by an unnecessarily large margin. With pure sine waves, or with any truly symmetrical waves, full-wave rectification makes it easier to remove the ripple from the rectified current, but such ripple as remains is more objectionable in that it is not of fundamental frequency; whereas the ripple which results from half-wave rectification is mostly of fundamental frequency, and if the shutter executes some movements in response to this ripple current, it simply alters the magnitude of the reproduced fundamental tone, but does not introduce a tone which was not in the original.<sup>17</sup> Among RCA engineers, the arguments for half-wave rectification have, in general, prevailed, although it is admitted that there are many situations in which full-wave rectification may be desirable. The argument that full-wave rectification may give excessive shutter opening would not have much weight were speech waves usually symmetrical, or random in their asymmetry, but oscillographic studies show that speech waves are predominately unsymmetrical and the higher peaks are nearly always pressure, rather than rarefaction peaks.<sup>17,18,19</sup> It is entirely possible to take advantage of this, and, by properly poling the recording system with reference to the microphone, to put the shutter on the side that calls for the lesser movements. This reduces the magnitude of all the ground-noise reduction problems, including ripple, clipping, and shutter noise.

## DESIRED OPENING CHARACTERISTICS

R. O. Drew, of the RCA laboratory in Camden, some time ago made a study of the audibility of various types of opening and closing characteristics. He mounted a metal flange around the circumference of a low-speed turntable and cut variously shaped curves in the flange so that the manner of intercepting a beam of light 1 inch high

by 0.020 inch wide could be varied by the simple expedient of cutting a piece of paper to the desired shape and sticking it to the flange. The amplifier gain was set so that full modulation of the light would have produced a rather loud signal. A standard RCA reproducing channel was employed with a No. 64-A monitoring loud speaker, which has good bass, although perhaps not quite as good as a standard theater speaker. This, however, was compensated by our proximity to the loud speaker. Results were also checked by listening with head-phones of special design which gave good bass. Fig. 10 shows some of the variations in the masks tried. A number of listeners participated. The conclusion was that although there was a slight difference in quality of the sound, the general audibility depended only upon the maximum slope of the cutting edge. This appeared to be substantially independent of the length of the slope.

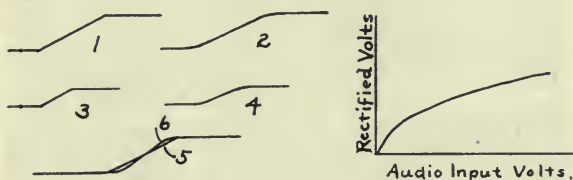


FIG. 10. (Left) Masks used in tests of audibility.  
FIG. 11. (Right) Desirable type of non-linearity in shutter response.

Rounding the corners, as indicated in curves 2 and 4 as compared with curves 1 and 3, did not serve appreciably to reduce audibility, and if the steepness had to be increased in order to bring the total time to the same value, the expedient of rounding the corners was definitely harmful. In other words, curve 6 was worse than curve 5. It is not often that results can be so simply stated as in this particular investigation, and no doubt it will be subject to minor corrections, but we believe that it is a reliable guide in design of ground-noise systems. We may therefore sum up the requirement of slit unmasking by saying that the shutter must never move faster than a specified velocity, but we do not care how quickly it is accelerated to this velocity.

So long as the maximum shutter velocity is kept below the specified value, there would appear to be no reason why the opening should not always be at the same rate even though the modulation may not be high. It would certainly appear reasonable to permit the highest



velocity which will be inaudible until the opening has reached normal clearance above the existing modulation. For example, when a weak sound starts, the shutter would open as rapidly but not as far as it would at the start of a strong sound. The non-linear relation between input and output or shutter deflection shown in Fig. 11 is a step toward making the opening rate more nearly the same for small as for large amplitudes of audio input.

Whether or not it would be better to employ full-wave rectification for steady-state conditions, there is certainly something to be said

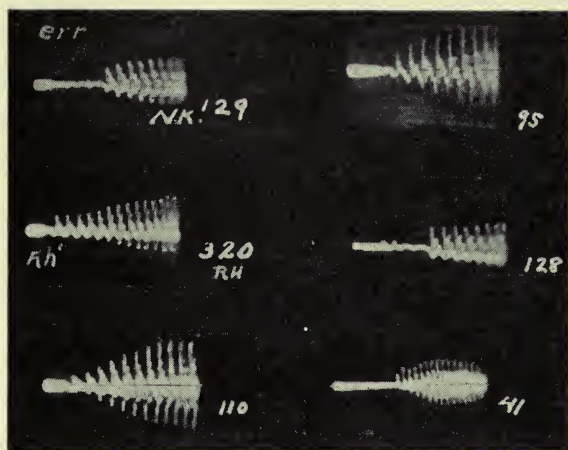


FIG. 12. Examples of speech sounds in which positive peaks appear in advance of appreciable negative peaks.

for utilizing waves of either polarity to start the shutter opening. Thus, assuming that the shutter and rectifier are so poled that the negative peaks are toward the shutter and that these are in general smaller than the positive peaks, it is still desirable that the motion of the shutter be initiated by the first indication of incoming sound. As was brought out in the paper "Starting Characteristics of Speech Sounds"<sup>19</sup> there are often positive peaks of appreciable magnitude considerably in advance of the negative peaks of comparable magnitude (Fig. 12). We might like to take advantage of this characteristic and permit the positive peaks to increase the clearance, or, in other words, to cause some shutter opening even though the

ultimate opening may more logically depend upon the height of the negative peaks only.

In discussions of ground-noise systems, we engineers have fallen somewhat into the habit of talking about "quick opening" of the shutter, when the characteristic we are talking about is not strictly a matter of speed but rather of amplitude. For example, to reduce clipping during the start of sounds, we may use a circuit or an adjustment of gain which will cause the shutter to open beyond the bare clearance point by a large margin. This, of course, results in faster shutter movements because the shutter has farther to go, but fundamentally it is not a part of the shutter timing. Fast shutter timing depends upon the filter design, the  $RC$  or the  $LC$  values, and number of filtering elements. These in general are the same for all amplitudes, and their effects are measured by applying transient impulses. On the other hand, the input-output characteristic, which includes the effect of the amplifier gain is measured under steady-state conditions by applying continuous input tones and determining the resulting shutter positions. It is therefore not logical to use such terms as "quick opening" or "fast action" to describe an input-output characteristic.

#### RELATION OF CLEARANCE AND MARGIN\* TO CLIPPING

In the absence of an anticipating system, we are constantly depending upon clearance to prevent clipping. The shutter always requires an appreciable amount of time to reach the opening which normally corresponds to the amplitude of the incoming waves. Fig. 13 illustrates the relation between delay, clearance, and clipping. Here an audio wave is assumed which increases rapidly in amplitude. If the initial clearance is small and if there were no delay in the shutter opening, it would follow curve 1 of Fig. 13(a) and there would be no clipping. Delay, however, which inevitably results when we try to filter out the audible components from our rectified voltage, causes the shutter movement to be represented by curve 2 instead of curve 1, and thus clipping occurs throughout the period of increasing sound amplitude. One way of providing clearance is to permit a substantial opening even at zero modulation. This will frequently prevent

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\*The term *margin* has come to be used to express an excess gain setting (expressible in db) above the value which would barely avoid clipping. *Clearance* is used to mean the actual distance by which the shutter image clears the peaks of the waves.

clipping, as illustrated in Fig. 13(b). Such a large residual opening, however, tends to defeat the purpose of ground-noise reduction. Increasing the gain of the ground-noise reduction amplifier also reduces

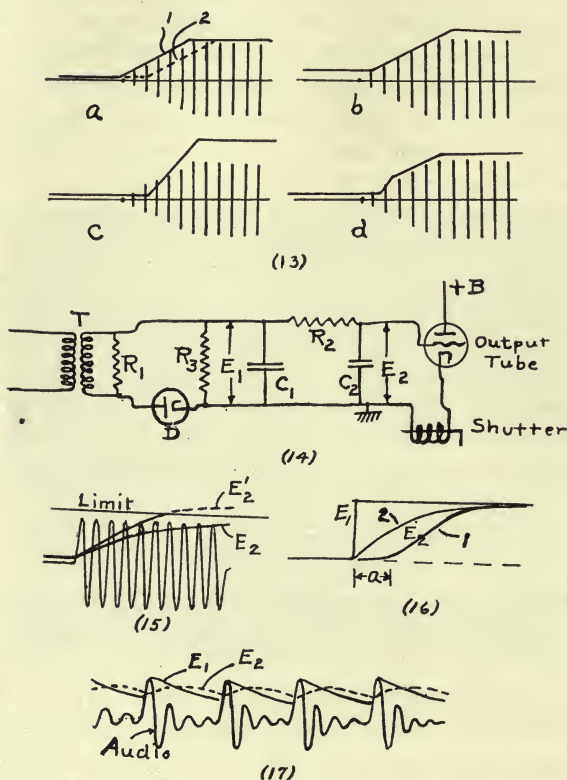


FIG. 13. Relation between margins and clipping.  
 FIG. 14. Fundamental type of ground-noise reduction circuit.  
 FIG. 15. Exponential opening characteristic and approximation to straight-line opening when margin and limit are taken into account.  
 FIG. 16. Effect of extra filtering upon opening characteristic.  
 FIG. 17. Sharp peak type of audio wave and resulting rectified and filtered voltages.

clipping, although as will be seen by comparing Fig. 13(b) with 13(c), it does not quite take the place of the larger initial opening so far as the first small waves are concerned. Since the gain is a question of ratio



of input to output, the mere expedient of increasing the gain results in excessive clearance for moderately high amplitudes once the full opening has been reached (see Fig. 13(c)). Fig. 13(d) shows the clipping relation with a small residual (or zero modulation) opening, but an input-output characteristic of the type illustrated in Fig. 12. This is generally regarded as the best practical compromise. The question may arise whether a crescendo of the type illustrated in Fig. 13 is typical of what is most commonly encountered. This question was the subject of an investigation reported by R. O. Drew and the writer.<sup>19</sup> We found that in speech sounds there were plenty of cases where the amplitude of the first wave was 50 per cent or more of that of the ultimate amplitude, but by far the most common type was that in which the amplitude increased linearly with time for the major part of the growth, with a slowing down of the rate of increase as the final amplitude is approached. Such a characteristic of the sounds to be recorded justifies writing into our specification for the ideal ground-noise system the stipulation that its input-output characteristic shall be such as to tend to afford a clearance of a substantially constant amount, rather than a margin of constant db excess gain. In other words, we should design the system with a view to maintaining about the same clearance at all amplitudes (when measured by a steady-state test).

One other characteristic might be asked for, although it may call for more complication than its value warrants: namely, that the margins (as set by the gain in the amplifier system, for example) shall be increased during periods of sound growth, as compared with the margin settings during steady-state conditions or during periods of diminishing sound amplitude.

We shall give further consideration to the subject of margins and how they can be provided. Up to this point it has been our purpose primarily to write specifications for an ideal ground-noise reduction system, or to formulate a statement of what we should like it to do.

#### SIMPLE TYPE OF GROUND-NOISE REDUCTION CIRCUIT

Fig. 14 shows, in schematic form, a rectifying and filtering circuit, which will serve as a basis of discussion. Conclusions in regard to the performance of a circuit such as shown are in general applicable to any ground-noise reduction system wherein a rectifier charges a condenser and the voltage across this condenser is filtered to produce an envelope voltage. For simplicity's sake in many of the arrange-

ments to be discussed, we shall omit some details such as providing suitable bias for various amplifier tubes. In the design of this circuit, the purpose was to provide a current to operate the shutter which is proportional to the actual peaks of the rectified waves. The output of a power tube (not shown) is stepped down by transformer  $T$  to provide a low-impedance audio supply for operating the rectifier. The loading resistance  $R_1$  lowers the supply circuit impedance, but its most important purpose is to keep the leakage reactance of the transformer from interfering with the delivery of very short pulses of current. When the audio voltage rises above the value to which condenser  $C_1$  happens already to be charged, current flows through the rectifier  $D$ , and charges  $C_1$  to substantially the full peak audio voltage.  $R_2$  and  $C_2$  constitute a stage of filtering to prevent abrupt changes from occurring in the voltage  $E_2$  which is applied to the grid of the output tube, whose anode-cathode current operates the shutter. (It has been assumed in our discussion, for the sake of simplicity, that the shutter responds instantly to changes in the current which actuates it. In actual shutters the inertia of the moving parts is kept as low as practicable, so that the characteristic just mentioned is at least approximated.) In order that the condensers may discharge and permit the shutter to return to the normal when the modulation ceases, the discharge resistor  $R_3$  is provided.  $C_2$  is made small in comparison with  $C_1$  so that it will not rob the latter of too much of its change.

Although there are many possible variations in rectifier and filter arrangements, the general features of rectifier, condenser to receive the charge, filter, and a discharge path, will be found to be common to nearly all ground-noise reduction systems, so that what is here said of Fig. 14 is, in general, applicable to other systems.

#### FILTERS

It is obvious that the voltage  $E_1$  produced by the rectifier is not suitable to apply directly to the shutter (or rather to the grid of the tube which operates the shutter), for it undergoes abrupt changes whenever a steep wave-front reaches the rectifier, and would therefore produce noise. The smoothly varying envelope current must be derived from the rectified voltage  $E_1$  by employing a low-pass filter, whose constants are so chosen as to permit rapid enough changes to follow the modulation amplitude, but to exclude the objectionable small and rapid variations, or rather to reduce these higher frequency

components to so small a magnitude that they will be practically inaudible. In Fig. 14, the filtering is provided by the resistance  $R_2$  and condenser  $C_2$ .

The most rapid shutter movements would obviously be those which result from suddenly applying a full-amplitude audio wave to the system. In this case, clipping is inevitable and the shutter should move out of the way as rapidly as can be permitted in view of the requirements for avoiding audible shutter thump. It will be recalled that in our tests for audibility it appeared that motion may begin instantly at full velocity and continue until the desired opening is reached, as illustrated in curve 1 of Fig. 10. A filter of the type shown in Fig. 14 comprising only one resistance and one condenser approximates the desired performance. If, for example, an audio wave, such as shown in Fig. 15, is applied to the system, the filtered voltage shown as  $E_2$  starts instantly to rise at a certain maximum rate which is set by the magnitude of the voltage and the values of  $R_2$  and  $C_2$ . The maximum audio voltage should obviously be that which corresponds to full modulation of the track. If there is no margin of excess shutter opening, the final movements of the shutter will be too slow, as shown by the curve  $E_2$ , but with a moderate margin the shutter motion will be at almost full velocity until the track is wide open as shown by  $E_2'$ .

In some ground-noise reduction systems a shunt resistance and series inductance control the filtered current instead of a series resistance and shunt capacity. These two types of filter have the same fundamental characteristic.

The filtering obtainable with a single stage employing only one reactive element and one resistance may not always prove adequate for removing the audible components of the rectified voltage, unless some special means, as will presently be discussed, are employed to reduce the amount of ripple coming from the rectifier, or, in other words, the ripple in  $E_1$ . This is particularly likely to be the case if the system is designed to make the shutter close rapidly when the modulation falls. For this reason, filters have been employed which give increased filtering, obtained either by using combinations of inductance and capacity or two or more stages of resistance and capacity. The effect of either of these expedients is to produce a toe in the opening characteristic, as shown in Fig. 16 in which curve 1 represents the characteristic of a two-stage or double reactance filter, as compared with curve 2 for the filter previously described. So far



as clipping goes, the delayed starting represented by the horizontal offset  $a$  is dead loss, and as has already been stated, curve 2 would cause no more thump than curve 1. There is nevertheless some excuse for employing the extra filtering elements. The problem of avoiding objectionable noise is not solely one of limiting the maximum rate of opening, although this is the only part of the problem where there seems to be a *necessary* compromise. Under steady-state conditions, the rectified voltage  $E_1$ , of course, contains components of many frequencies. When the characteristics of the ear and those of the reproducing system are combined, the result is that loudness increases with frequency at a very rapid rate in the low-frequency range. The attenuation of the higher frequencies by a single stage of resistance-capacity filtering does not increase fast enough to compensate for the increased audibility of the high-frequency components. On the other hand, other types of filters can be made to discriminate more rapidly against the high frequencies. The easiest way to get complete suppression of audible components is to use the extra filtering. Were there no other way of avoiding the audible noise, we should have to resign ourselves to the use of the extra filtering with its consequent delay in shutter opening. It is much better, however, to reduce the disturbance at its source, and there are a number of factors by which the ripple voltage, which has to be filtered out, can be reduced in magnitude. When this is done, it is quite possible to meet the noise requirements with the single-stage of filtering.

#### PEAK-READING\* PROPERTIES

The voltage (or current) at the output end of a low-pass filter depends upon the average value at the input end rather than upon its peak value. Thus in Fig. 17,  $E_1$  and  $E_2$  have the same average value. Therefore, it is the average value of  $E_1$  (rather than the maximum value) which we wish to make as nearly as possible equal to the peak of the audio wave applied to the rectifier. In order to meet this requirement, the input circuit and rectifier must be of low enough resistance so that the condenser will reach full charge during the time which the audio wave applies this voltage. This is not very important in the case of sine waves, for if they are of low frequency the voltage is sustained for a considerable period of time; while if they

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\*The term *peak-reading* is borrowed from voltmeter specifications to describe a system in which the shutter opening depends upon the magnitude of the peaks of the audio waves, rather than on their average or their rms value.

are of high frequency and the condenser does not receive full charge during the first cycle, the charging will be completed by more waves following in quick succession. In actual recordings, however, waves of the type shown in Fig. 17 are extremely common, not necessarily in the exact form indicated, but waves whose peaks are of very short duration and in which an equally high peak does not occur until a whole cycle (of fundamental frequency) later. Waves of this type present the greatest difficulty in providing peak-reading characteristics. The first requirement for a peak-reading system is a low-resistance supply circuit and rectifier, in order that  $E_1$  may reach the full peak value in a single half-wave of a high-frequency voltage. The input circuit impedance must also be free from appreciable inductive reactance. The next requirement is that there shall not be too much discharge of condenser  $C_1$  between the moments of charging. Obviously, this requirement is met when the discharge or closing rate is made very slow, for example, by using a high value of  $R_3$  in Fig. 14. With variable-area recording a slower discharge has been acceptable than in the case of variable-density recording. Values of  $C_1$  and  $R_3$  have been widely used for area recording, which give a time constant of 0.045. Even with this timing, however,  $C_1$  could lose about 33 per cent of its charge between peaks spaced 10 milliseconds apart (corresponding to a 100-cycle fundamental). With faster closing, as called for in density recording, peak-reading properties are further impaired. This criticism does not apply particularly to the circuit of Fig. 14. The only type of circuit which will give true peak readings is one in which the rectifier is virtually unloaded and the condenser does not discharge appreciably during one cycle of fundamental frequency. Therefore in the design of a ground-noise reduction system, it should be the aim to come as nearly to meeting these two conditions as is practically possible. A heavily loaded rectifier will give something between an average and an rms value of the applied voltage, and thus far from the peak reading.

#### RELATION OF MARGIN TO PEAK READING

As has been stated, ground-noise reduction systems are invariably operated with a certain margin of excess gain, usually adjusted by a potentiometer volume control in the audio amplifier which feeds the rectifier. It is customary to set the margin by applying a 1000-cycle wave of specified amplitude and adjust the ground-noise reduction gain until the shutter is opened to a specified point. A margin of 6

db would mean that any change in the amplitude of the audio waves as recorded on the film would result in a shutter image movement of exactly twice the amount. If, for reasons already discussed, the shutter movement does not bear a linear relation to the audio amplitude, then we can not speak of so many db margin except in connection with a specified test-tone level. The margin serves a twofold purpose. It prevents clipping in case of an increase in audio amplitude, provided the increase is less than the clearance which this margin has produced; and in the second place, margin is required under steady-state conditions because ground-noise reduction systems are in practice far from truly peak-reading, adjustment for a large margin on sine waves, for example, being only sufficient to give bare clearance for a wave of equal peak height but having the shape shown in Fig. 17. Peak-reading properties are just as important for the purpose of maintaining the margins during crescendos as they are for maintaining them during a steady state. Consider, for example, a series of waves of increasing amplitude but of comparatively low fundamental frequency. If there is failure to charge the condenser completely during a peak or if it discharges between peaks, the intended margin to allow for crescendo is lost, and again the only cure is to provide still more margin of gain. We thus see that poor peak-reading properties must be compensated by substantial increases in margin adjustments. The margin may not be excessive with certain types of wave, while with others it will be decidedly more than necessary. The obvious penalty for employing more margin than necessary is an increase in ground-noise. Since ground-noise is scarcely a problem when the modulation is high, engineers are inclined to dismiss the erratic and often excessive margins as of no consequence, to set the margins high enough to prevent excessive clipping, and consider the system to be working satisfactorily. Such a viewpoint, however, ignores the most important factors. It is true that some excess of clear film when the modulation is high does little harm, but what about when the modulation stops? The shutter has farther to go, and a faster rate of closing is necessary to prevent audible ground-noise after the modulation. This aggravates ripple, making more filtering necessary, and also makes the peak-reading properties worse. Again during opening, if the shutter moves farther than necessary, it must also move faster than necessary. This results in more trouble from shutter thump and more danger of noise due to small movements of the shutter. The cure for the last trouble is again more



filtering, with consequent increased delay of shutter action which must be compensated by larger margins in order to prevent excessive initial clippings. Poor peak-reading properties (by which is here meant inconsistent relationship between peak height and shutter opening) thus initiates a vicious circle of corrections for faults, with an exaggeration of all the troubles to which ground-noise reduction systems are heirs.

We shall next consider some specific circuits and proposals for improving the action of ground-noise systems.

#### SINGLE SIDE-BAND HIGH-FREQUENCY SYSTEM

An ingenious and interesting proposal for improving filtering, while still permitting as quick operation as may be desired, consists in modulating a high-frequency current by means of the audio waves. This is done in a balanced modulator which eliminates the carrier frequency. A sharp filter then removes one of the side-bands. The remaining side-band is a measure of the magnitude of the audio frequency, and, if rectified, will give a steady current proportional to the audio amplitude. Thus if we start with a 100-cycle audio input and use this to modulate a 20,000-cycle carrier, there would result voltages of 19,900 and 20,100 cycles as side-bands. The magnitude of the side-bands would be directly proportional to that of the original 100-cycle current. Only one of the side-bands, the 20,100-cycle one, for example, is applied to the rectifier. A low-pass filter having a cut-off frequency of several thousand cycles would serve to remove the high-frequency component after rectification, and such a filter would not need to produce appreciable delay.

On the basis of a pure sine wave input, the system just described appears to be perfect. As soon, however, as we assume that the audio waves contain several component tones, much of the advantage of the single side-band system disappears. Let us assume, for example, an audio wave having equal components of 100 and 200 cycles. The upper side-bands would then be of 20,100 and 20,200-cycle frequency and would be equal in magnitude. The sum of these two voltages would be a high-frequency voltage modulated 100 per cent at a 100-cycle modulation note. Rectification would result in a continuous current proportional to one of the high-frequency components, superimposed on a 100-cycle wave having a maximum value the same as that of the continuous current, thus modulating it by 100 per cent. It would therefore be necessary to filter out the 100-cycle

component by means of a low-pass filter comparable with that required for one of the direct rectifier systems already discussed. It appears that in this case nothing at all has been gained by the complication of modulating the high frequency. With many audio wave-forms, the result of rectifying the upper side-bands would probably be intermediate between the results with the pure sine wave and the rather bad case just discussed. So far as the writer has been able to judge, it is doubtful whether with complex waves the single side-band system would offer enough benefit to justify the circuit complexities.

The system just described must not be confused with the systems employing carrier current subsequent to the production of a filtered envelope voltage.<sup>20</sup> Such systems have been in successful use, but in these the carrier-current feature may, so far as the discussions in this paper are concerned, be regarded simply as serving as an amplifier to provide an output current proportional to the filtered voltage.

#### ADVANTAGES OF DELAYED CLOSING

Referring again to Fig. 17, it is evident that the amount of ripple in the voltage  $E_1$  which has to be filtered out, and also the drop below peak value, are reduced by slow discharge. In attempting to formulate how we should like a ground-noise reduction system to perform, we specified that we should like the closing to be represented by curve 1 of Fig. 9 rather than curve 2. If  $C_1$  of Fig. 14 discharges in the normal exponential manner as illustrated by curve 2 of Fig. 9, the filter itself will cause  $E_2$  to discharge according to a curve something like no. 1 of the same figure, but this is not what we want or intended when formulating the specification. Once a fraction of the charge has been lost from  $C_1$  the circuit will not continue to hold the shutter open for the arrival of the next peak. No appreciable discharge of either condenser should take place until the lapse of a certain time after  $C_1$  received the charge. The voltage across  $C_1$  should thus be represented by curve 1 of Fig. 9. It is not necessary that the entire discharge shall be at a low rate (such as would be caused by using a high resistance for  $R_3$  of Fig. 14), in order to give the peak-reading and low-ripple properties to the ground-noise system. If a full period of the audio wave passes and a new peak does not arrive, this is good enough evidence that discharge at normal rate should begin so that the envelope curve will follow the modulation down.

The advantages of delayed discharge in reducing ripple apply in an even more important way to the opening characteristic than to steady-

state. Fig. 18 shows a crescendo of a wave of low fundamental frequency, and the rectified but unfiltered voltage  $E_1$  derived from it, first, with a moderately high initial discharge rate (curve 1) such as would be given by a simple resistance discharge path as in Fig. 14 and fairly rapid closing; and, secondly (curve 2), with slower closing or delayed discharge, such that  $C_1$  would not discharge appreciably between the charging peaks. In either case it will be noted that  $E_1$  rises by steps instead of uniformly as would be wanted for minimum noise. In other words, superimposed upon the desired uniformly rising voltage is a strong ripple, much larger than the ripple which will be produced after full amplitude is reached. This ripple is much worse in curve 1 than in curve 2. When the objective is to suppress noise to the point where it is inaudible a few db difference in level may become very important. During crescendos not only is the ripple

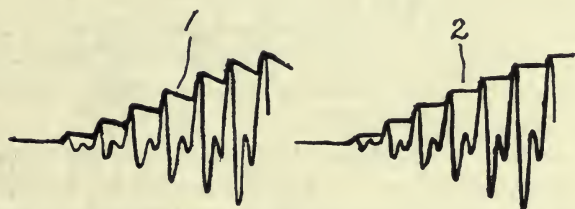


FIG. 18. Step effect on charging and exaggeration of same by discharge between input peaks.

larger than during a steady state, but the fact that it is superimposed upon a continuous change which is itself as rapid as can be tolerated, makes the ripple at this time more objectionable than an equal ripple under steady-state conditions. The ripple in the filtered voltage  $E_2$  will, of course, be much less than that in  $E_1$  as shown in Fig. 18, but whatever increases the ripple in  $E_1$  will increase it in  $E_2$ . Two factors have undoubtedly contributed to toleration of unnecessarily large crescendo ripple: (1) the quality of the sound resulting from a short train of low-frequency waves is so similar to that produced by the necessary shutter change that the latter may often be blamed for what is in part due to the former, and (2) crescendos are so often accompanied by clipping that either the clipping distortion masks the low-frequency disturbance, or else all the faults are lumped together and treated as inevitable.



## CIRCUITS FOR PRODUCING DELAYED CLOSING

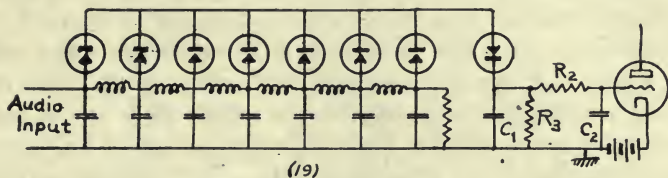
A number of arrangements have been studied with a view to providing a discharge characteristic approximating that of curve 1, Fig. 9. It is the writer's belief that further improvements in ground-noise reduction systems will involve employing some such expedient, the problem being to select the most promising of the suggestions considered, and then to prove on actual test that the improved performance is worth the added complication. In judging on the basis of test whether a complication is justified, the writer would like to emphasize a point of view which he believes to have been frequently vindicated. If a device theoretically performs better than another (without sacrifice of such factors as reliability), and if the theory is recognized as sound, it may often occur that tests on a limited scale will fail to show an impressive advantage, but the better functioning device should be employed on the simple probability that ultimately its superiority will show up in the quality of the product. Ground-noise reduction itself is an example of such an experience. Robinson's first tests convinced him and some of his associates that the principle was worth while, but others were not convinced. Ultimately its importance became established.

Fig. 19 shows a circuit proposed for the purpose, not of preventing the discharge of condenser  $C_1$ , but of renewing the charge at short intervals covering a total period which might be of the order of ten to twenty milliseconds. The transmission line shown would, of course, be damped at the end to prevent reflections, and would have to be of low enough impedance not to be appreciably loaded by the rectifiers. There are, of course, numerous modifications involving the same principle.

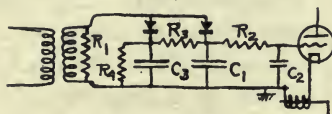
An inductance in series with  $R_3$  of Fig. 14 would delay discharge, producing a curve with a shoulder. On first thought this appears to offer a possible solution for the problem of delaying discharge. Unfortunately, however, inductance acts in the manner described only when there was no previous current flowing through it. Under steady-state conditions, it is not of any appreciable help toward giving peak-readings. The inductance would, however, serve a useful purpose in that it would reduce the amount of discharge during crescendos, thereby increasing the margin.

Fig. 20 shows a modification of the circuit of Fig. 14 in which an additional condenser  $C_3$  is charged simultaneously with  $C_1$ . Assuming that both these condensers become charged to the full peak voltage,

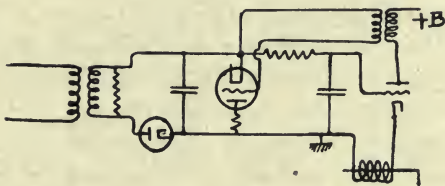
$C_1$  does not begin to discharge rapidly until the voltage across  $C_3$  has fallen considerably. This circuit produces a result in the right direction, but if the resistances are so chosen that  $C_1$  will be discharged down to about 10 per cent of its original charge in the same time as



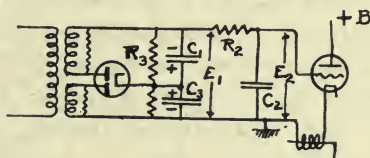
(19)



(20)



(21)



(22)

FIG. 19. Circuit proposed by the writer for providing successive charges.

FIG. 20. Two-stage discharge circuit.

FIG. 21. Circuit of S. Read, Jr., employing grid-controlled discharge.

FIG. 22. Differential circuit of H. I. Reiskind.

in the circuit of Fig. 14, the shoulder which the Fig. 20 circuit produces in the discharge of  $C_1$  does not extend as far as we should like.

Fig. 21 shows an arrangement proposed by S. Read, Jr.,\*\* employing an expedient first suggested by G. L. Dimmick:\*\* namely, the deriving of a control voltage from the secondary of a transformer whose primary is in series with the output tube. Dimmick showed

\*\*RCA Manufacturing Co., Camden, N. J.

that the voltage induced in the transformer secondary could be made effectively to oppose the discharge of capacitor  $C_1$  by connecting the transformer winding directly in series with  $R_3$ . This opposing voltage (being proportional to the rate of change of current through the output tube) is directly proportional to the drop across  $R_2$  and persists, but with diminishing value, until  $C_2$  has become charged to the same voltage as  $C_1$ . This helps materially when the audio voltage is first applied or during crescendos, but under steady-state conditions the retarding voltage becomes too small to do much good in the way of reducing ripple. Dimmick worked out several arrangements for increasing the opposing voltage effect without permitting it ever to raise the condenser voltage  $E_1$  above the audio peak value. Read employed a triode through which the discharge takes place, and used the transformer voltage to bias the tube to cut-off. By using a high-"mu" tube and a large number of turns on the transformer, the discharge can be blocked so long as there is even a small rate of increase in the voltage across  $C_2$ . The biasing voltages will be properly timed, for the moments of maximum rate of rise of voltage across  $C_2$  occur just after  $C_1$  has received a charge.

It has already been stated that a second stage of resistance-capacity filtering gives a shoulder on the discharge curve such as curve 1 of Fig. 9. Mathematical analysis of such a circuit shows that the equation for the discharge curve takes the form of the difference between two exponential decay curves, one having a large initial value and a slow time-constant and the other of smaller initial value and more rapid discharge. The initial slopes of the two curves are of the same value, but being of opposite sign, the resultant or difference curve starts horizontally, but the effect of the smaller component soon dies out, and the remainder of the discharge practically coincides with that of the larger circuit. Mr. H. I. Reiskind\*\* has experimented with a circuit shown in Fig. 22 in which the total voltage  $E_1$  is equal to the difference between the voltages across two condensers, both charged simultaneously and oppositely but to different voltages, the condenser charged to the lower, subtractive voltage being shunted by a resistor which discharged it more rapidly than the other. With this arrangement, greater freedom in choosing constants was obtained and the desired discharge curve could be produced without some of the limitations imposed by other methods.

Fig. 23 is from British patent No. 505,011 to Karl Schlegel. The letters designating such condensers as have counterparts in Fig. 14



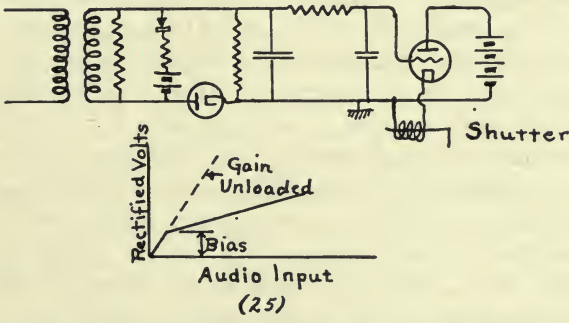
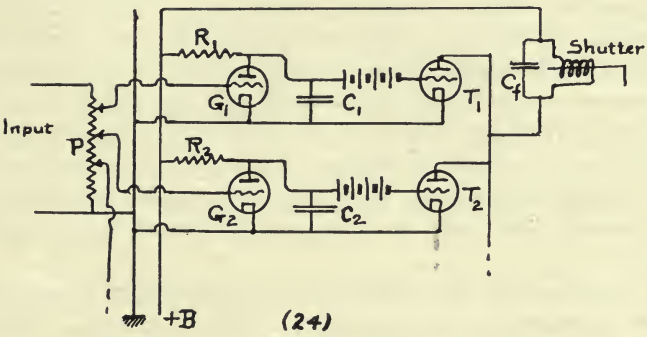
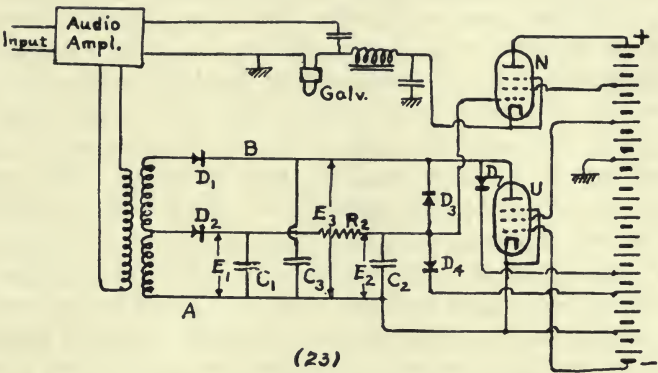


FIG. 23. Circuit of Karl Schlegel, Brit. Pat. No. 505,011.  
FIG. 24. Circuit of J. B. Gehman, using gas-discharge triodes.  
FIG. 25. Rectox recording unit of G. L. Dimmick and type of response curve produced by it.

have been changed from those shown in the patent to correspond more closely to the designations already used in this paper. Thus  $C_1$  is charged to the peak value of the audio wave, and the voltage across it is designated as  $E_1$ . After smoothing by the filter  $R_2$  and  $C_2$ , the voltage (now designated as  $E_2$ ) is impressed upon the grid of the output tube  $N$ . The discharge path in this circuit is across  $C_2$ . There is, however, no discharge path of fixed resistance. The rectifier element  $D_4$  is so poled that it simply sets an upper limit to the voltage  $E_2$ . The only discharge path is through rectifier  $D_3$  to conductor  $B$  which is charged by the extra rectifier  $D_1$  to a voltage  $E_3$ , higher than  $E_1$ . Rectifier element  $D_3$  is so poled that it prevents  $C_2$  from receiving any charge from the high-voltage rectifier  $D_1$ , but does permit  $C_2$  to begin to discharge after  $E_3$  has fallen to a lower value than  $E_2$ . ( $D_1$  is another voltage limiter.) Instead of a simple resistance for discharging condenser  $C_3$  (which is charged to the voltage  $E_3$ ) the pentode  $U$  is employed. It is well known that a pentode has a constant-current characteristic, and the purpose is evidently to cause the discharge curve to take the form of a straight line, the voltage falling at a constant rate, instead of along a sagging curve of the exponential type. The patent does not show any provision for making this constant-current effect work down to complete discharge or zero plate voltage.

Fig. 24 shows a circuit developed by J. B. Gehman.\*\* The shutter current is supplied by several output tubes  $T$  in multiple. Only two are shown in the figure, for illustration, but about five circuits such as shown would be employed. Each output tube is adjusted to carry a desired fraction of the total current. The tubes  $G_1$ ,  $G_2$ , etc., are of the gas triode type. The audio input voltage is applied across the potentiometer  $P$ , and the grid of each gas tube is connected to a suitable point on the potentiometer, such that they are rendered conducting at successively higher voltages across potentiometer  $P$ . When the grid of any tube,  $G_1$ , for example, reaches the tripping potential, the tube at once carries a large current, completely discharging condenser  $C_1$ . Since the plate voltage drops to zero, the conduction ceases as soon as  $C_1$  is discharged. Thereupon,  $C_1$  immediately begins to charge again through resistance  $R_1$ . The output tube  $T_1$  is so biased that its plate current is completely cut off when the voltage across  $C_1$  is below a specified value. Thus the plate current of tube  $T_1$  drops from the normal level which it has during periods

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\*\*RCA Manufacturing Co., Camden, N. J.

of no modulation, to zero, remains at zero until  $C_1$  has charged to the specified value, and thereafter rises and approaches normal zero modulation value again at a rate determined by  $C_1$  and  $R_1$  and the supplied voltage. Filtering is provided by shunting the shutter  $S$  by a capacitor  $C_f$ .

At zero modulation, the shutter current is the sum of the plate currents of all the tubes. A low-level audio wave will trip one gas tube and decrease the current of the corresponding output tube to zero. The next higher level (chosen by the position of the next contact on the potentiometer  $P$ ) will trip the first and second tubes. Still higher level will trip three tubes, and so on. The filtering must be so adjusted that excessive thump will not occur if all tubes are tripped at once. If they are tripped successively by the audio wave, the fall in total current will be less rapid. Whatever value of current is established by the level of modulation and the number of tubes biased to cut-off, this value will be retained until a predetermined interval has elapsed after the passage of the last audio wave of sufficient magnitude to trip these tubes. If, after a certain group of tubes has been tripped, another audio wave of the same amplitude occurs, the same gas tubes will again conduct current and discharge their condensers. Recovery must then start over again. This is true, regardless of whether the previous recovery had progressed far enough to cause any of the output tubes to carry plate current or not. If the new audio waves reach the input circuit before conduction through the output tubes begins, then there is no ripple whatever in the output or shutter current, for each output tube in question continues completely cut-off. Ripple begins to appear when the interval between audio waves is greater than the period of complete cut-off, which interval is fixed by the design or adjustment of the system. Ripple becomes progressively greater as the frequency is lowered below this point, but would in no case be worse than that of a ground-noise system of the usual type having comparable total discharge time. The shutter opening, instead of being a continuous function of input level, has a fixed set of values. About five output tubes would make the steps small enough to maintain the margins within suitable limits.

The circuits just described illustrate a few of the expedients being studied. In most of the illustrations the circuits have been simplified down to the bare essentials for explaining the general principles, the actual practical circuits having numerous elements which do not appear in these sketches.



## CIRCUITS FOR PROVIDING SUBSTANTIALLY CONSTANT MARGIN

The provision of nearly constant clearance requires that the gain or ratio of output to input shall be large for low-level inputs, and decrease as the level is raised. This calls for decidedly non-linear elements, operating either on the audio waves, or on the rectified voltage or current, or in the design of the shutter itself. In the arrangement illustrated in Fig. 14, modulation reduces the plate current from an adjusted initial value to zero current at full modulation. The toe of the plate current *vs.* grid voltage curve of the output tube tends to give the system an arched curve of shutter displacement *vs.* input voltage, somewhat resembling Fig. 12. B. Kreuzer\*\* proposed to produce a more pronounced effect of this kind by employing exponential output tubes. Since it was felt that a still steeper initial rate followed by a sharper break was desirable, G. L. Dimmick proposed controlling the shape of the curve by means of a biased loading circuit with copper-oxide rectifiers as illustrated in Fig. 25. This gives an input-output characteristic which is very steep at the start, followed by a much slower subsequent increase. Thus small modulation is sufficient to produce a substantial margin of shutter clearance, and thereafter the clearance may remain about constant, or increase slightly until full opening is approached. Tests have shown this to be definitely helpful in reducing initial clipping.

## ANTICIPATION

It has been proposed to delay the recording of the sound for ten to twenty milliseconds, or perhaps more, after it has been picked up by the microphone. On the other hand, the audio voltage would be impressed on the ground-noise reduction rectifier without delay. This would give the shutter a corresponding time to move out of the way in anticipation of an increase in recorded amplitude. One of the obvious expedients for providing such delay would be to use a speaker unit and a microphone connected through a tube, perhaps twenty feet long, and record the output of the microphone instead of the original sound. Another delay system consists in recording on magnetic tape or wire, and reproducing by means of a pick-up a suitable distance from the recording magnet. A method of delaying sound for a short interval by illuminating a moving luminescent surface with modulated light, and picking up photoelectrically a short distance away, has been described by Goldmark<sup>21</sup> who has used this principle

to produce reverberation effects. Another method would employ bound electrostatic charges on a moving surface.<sup>22</sup> Recording on any known medium is of course possible, but the types of record which can be erased and leave the carrier ready for fresh recording are obviously preferable.

It will be noted that the audio waves to be delayed are not the ones which control the ground-noise reduction system, for which purpose considerable distortion might be tolerated, but are the waves which must be impressed on the recording device. Therefore, distortion is not to be tolerated. It is the unwillingness on the part of engineers to introduce an element which could even threaten to produce distortion which has no doubt been largely responsible for failure to employ one of the expedients just described. Since it is the devices which convert waves to mechanical or other forms and convert them back to electrical waves, which are responsible for most distortion, and the limitations of most recording mediums (wax, lacquer, magnetic materials, *etc.*) result in noise, the ideal method of providing delay would be one which involved no conversions, as, for example, an electrical transmission line. It should be possible and not difficult to build such a line which would produce the necessary delay without causing measurable distortion. The requirements, however, are such that it would be an expensive piece of equipment. Let us assume, for example, that the audio channel must be good to 10,000 cycles. The line would almost of necessity be made with lumped capacities and inductances and would thus act as a low-pass filter. The cut-off frequency for a low-pass filter is reached when there are  $\pi$  coils per wavelength, but serious phase-distortion occurs before the cut-off frequency is reached. It would therefore not be safe to count on less than four or five coils per wavelength, and there is question about this figure. If the sound is to be delayed 0.02 second, the length of the line would have to be 200 wavelengths of 10,000-cycle current; therefore, there would have to be at least 1,000 coils and condensers. The attenuation will be very high unless the elements are of very low loss, and the series and shunt losses must be closely balanced in order not to cause decided distortion. The electric transmission line as a means of producing delay may find a place, but it is not surprising that it has not come into use. The acoustic delay tube seems to be about the nearest approach to a satisfactory device, but the writer is inclined to think that sound departments are right in not taking any chances of distortion or of the failure of any device to function per-

fectly, tolerating rather the amount of clipping which the ground-noise system, in the absence of anticipation, causes.

In original recordings, the direct positive system<sup>13</sup> permits anticipation. The blackening for ground-noise reduction purposes is accomplished by an auxiliary light-beam which operates on the film after it has passed the recording light-beam. This system has much to commend it as a means of making original recordings. So far as the writer can see, it can not be applied to variable-density recording, except in conjunction with electric compressors, which would raise the modulation when the fogging beam is employed. Original recordings can also be made without any clipping troubles by adopting class *B*<sup>23</sup> or class *A-B*<sup>24</sup> push-pull recording. The class *B* system was adopted several years ago for single-film newsreel work,<sup>25</sup> one of the important considerations being that low ground-noise is obtained without the necessity of any ground-noise reduction equipment, and more recently has been used for high-quality studio recording.<sup>26</sup>

When we come to re-recording, it would appear that anticipation can be very easily obtained by the simple expedient of employing a second reproducing system with suitable longitudinal offset. The first reproducing system operates the ground-noise reduction and the second reproducing system provides currents for recording. There is little question that this system would have been adopted long before this were the re-recording operation a simple matter of a single reproducer. The elaborate systems of re-recording employed in the motion picture studios, involving up to a dozen film-phonographs, each contributing a selected portion of the program, so complicates the problem of providing anticipation that it has, in most cases, been regarded as impracticable. Each of the contributing film-phonographs would need to have a second reproducing system. The entire mixing system would have to be in duplicate, with single control, and a duplicate amplifier and volume-control system would be needed for operating the ground-noise reduction system of the recorder. Even this complication might be accepted if the benefits of anticipation were fully appreciated. This, however, comes down to a matter of opinion. We hear many faults in reproduction and can not always ascribe them to specific apparatus. The elimination of all disturbances due to quick opening and all distortion due to initial clipping would seem to the writer to be worth a considerable price in added equipment, particularly if the original recordings are made



in such a manner that unclipped sound-tracks are available as originals. It appears to the writer that the above-described re-recording system with complete duplication of reproducing channels might be avoided while still obtaining a large part of the benefit of anticipation. In motion picture work, it is common for a single film-phonograph to supply practically all the dialog, while the others are supplying music and other effects which are quite secondary both in importance and amount. The dialog might all be carried by a single film-phonograph with double reproducing optics. The output from its auxiliary optical system would be supplied to an extra ground-noise reduction amplifier at the same gain as the output from its regular optical system. The outputs of the regular and the auxiliary ground-noise reduction amplifiers would be combined through rectifiers in such a way that the shutter opening corresponded to whichever of the two systems produced the higher voltage at the moment. This would not increase any of the steady-state margins, nor would it in any way jeopardize the recording, since the regular ground-noise reduction would function exactly as at present. In fact, about the only time that the auxiliary system would affect the shutter movement would be when the shutter ought to be opening but the regular signal has not yet reached it. The advantages of the anticipation system are:

- (1) Avoidance of all initial clipping.
- (2) Permitting less rapid opening and thereby avoiding dangers of audible disturbance.
- (3) Ability to reduce margins (because present margins must be exaggerated in order to allow for a surprise factor).
- (4) Permit quicker closing. Present closing speeds are dictated by the necessity, on the one hand, of suppressing ground-noise as promptly as possible after modulation has fallen; and on the other hand, the danger that every time the track closes down there is likelihood of clipping on the next rise of modulation. Anticipation by eliminating the latter danger, makes it practicable to follow the modulation down as rapidly as desired.

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#### DISCUSSION

DR. FRAYNE: Which of the following three elements are the limiting factors in obtaining the maximum amount of noise-reduction: (1) the noise-reduction

circuit; (2) the type of modulator; or (3) the film medium, in their order of importance? Where do you stop—10 db, 20 db?

MR. KELLOGG: In the variable-area system the limit is set by how narrow a clear area we can employ when the modulation is low. In our Class *B* system, we can reduce the residual opening to such a point that there would be no appreciable advantage in going any further. Practically the entire film is black. In a standard variable-area recording, we have over a long period of time worked with about a 2-mil width of clear film.

I do not know whether I had better try to answer the question as to what would make the most difficulty in going further. May I reciprocate by asking how far you can go on the density system?

DR. FRAYNE: In push-pull systems it has been found feasible to use up to 20 db of noise-reduction. Common practice with single-track recording is to use not more than 10 db.

MR. SCOVILLE: In the circuits shown by Mr. Kellogg the filters were composed mainly of resistance and capacity elements. In Western Electric variable-density systems we found that type of filter inadequate. There may be a good reason for this. With variable-area recording the release time is usually quite long, whereas with the variable-density it is relatively short. In consequence of that we found it necessary for variable-density recording to have the maximum filtering for a given set of timing conditions. That has always called for very carefully designed inductance and capacity filters with rather critical adjustment of operating time.

I believe Mr. Kellogg stated that with filters using inductance and capacity he found an initial delay in the attack period that was undesirable. We find it possible to get around that by the use of a modified *M*-derived type of filter, which in effect tends to short-circuit the inductance in the initial part of the attack period and thus permits a sharp build-up of bias current.

MR. KELLOGG: Have you found that the *M*-derived type of filter gives you an almost instantaneous start? Do you know of any experience that either confirms or contradicts what I have reported from our tests: namely, that the velocity of movement is the determining factor in audibility, and that the sharp corner did not seem to do any harm? We did not feel the test was necessarily final.

MR. SCOVILLE: The velocity and amplitude of movement are probably the chief factors. It is surprising to make comparative tests of filtering for several different types of filters, all, however, having the same attack and release times, and find how widely the effectiveness of filtering varies. The least efficient type of filter in our experience has been the simple capacity-resistance type.

MR. KELLOGG: My advocacy of the simple capacity-resistance filter is based upon the assumption that we would be able to reduce the necessity of filtering by some of the measures I mentioned in the latter part of the paper. It seems to me that is the direction in which we should like to go. I check your point that it is the relatively slow closing in the variable-area system that enables us to get away with the simpler filter.

MR. LIVADARY: Mr. Kellogg stated that he had investigated thoroughly the initial rate of increase of the signal and had arrived at certain times that he regarded as satisfactory for the initial build-up.



Later he spoke of the necessity of accelerating the opening time around zero time. Would that create any difficulties such as shutter bump?

MR. KELLOGG: The tests I reported were not made on an actual ground-noise reduction system. They were made by means of a moving mask that uncovered an illuminated slit. So far as we could tell, there is no objection to having the light begin instantly to change at the maximum rate.

MR. ALBIN: Regarding the use of the half-wave *vs.* the full-wave, do you have any preference, in view of conditions that exist—for example, asymmetry of the wave, and the fact that the other half of the rectifier ordinarily would not serve any purpose because one-half of the cycle would open the modulator, in any event, opposite from the direction that would cause overload?

In other words, take an analogy to a biased light-valve modulator: One-half of the cycle will open the valve, so that that half of the modulation would not need a rectifier to operate it. The advantage of the full-wave rectifier then would be to utilize the other half-wave and thereby give the noise-reduction cancellation a little advance start, so as to gain a little in time.

Does that again warrant the use of the full-wave rectifier over the half-wave rectifier in your opinion?

MR. KELLOGG: An ideal system seems to me to be one that utilizes full-wave rectification but employs some means for preventing peaks that are away from the shutter from increasing the opening much beyond that given by the half-waves on the shutter side. This, and the possibility of permitting the positive waves to contribute only during the start are discussed in the paper.

As is shown in the illustration of the cathode-ray oscillograms, quite often the positive waves appear in appreciable amplitude considerably before the negative waves. It would be distinctly desirable to use them, and I think full-wave rectification has that to be said in its favor.

Of course, we all grant that full-wave rectification may reduce the ripple that has to be filtered out, but I think that the advantage of this is overestimated. Unless there is pretty good symmetry the filtering advantage of the full wave tends to be very much cut down.

MR. ALBIN: The disadvantage of full-wave over half-wave rectification lies in the fact that the margin might be excessive if the wave were considerably asymmetrical. Is that correct?

MR. KELLOGG: That expresses it very well, I think.

MR. ALBIN: You would then say that that is not sufficient to discourage the use of the full-wave rectifier; in other words, the faster opening still warrants the full-wave rectifier?

MR. KELLOGG: That is a balance of one thing against another, upon which I hesitate to express an opinion. Before I would strongly advocate the half-wave against the full-wave rectifier, I would want to make sure that we were going as far as possible in taking advantage of polarity, so as to keep the longer, higher peaks away from the shutter, and also that we were doing something to reduce the ripple at its source, as I have described. With those steps taken perhaps the argument would be in favor of half-wave rectification.

MR. DIMMICK: With reference to Mr. Livadary's question, Mr. Kellogg mentioned the fact that the intensity of the shutter bump depended mostly upon the slope, or rate of rise of the unfiltered voltage, and not so much upon shutter

amplitude. I do not believe he intended to indicate that amplitude is not a factor. For a given slope, or rate of rise of the unfiltered voltage, the intensity of the sound goes down as the amplitude of the portion having the steep slope is lowered.

In the system to which Mr. Livadary referred, the portion that has the increased slope is of very small amplitude, and we have found by experience that an increased slope can be tolerated over that portion, with a very desirable result.

MR. KELLOGG: I might add that the sort of input-output curve I was showing, with the sharp shoulder, represents the rectified voltage before the filtering. After it has been through one stage of resistance-capacity filtering the contribution of that little shoulder to increasing the slope of the filtered voltage is almost negligible, provided, as Mr. Dimmick has said, that the steep portion is short, but it does improve the promptness with which the motion starts.

MR. LORANCE: The statement was made, I believe, that the problems of noise-reduction in variable-area and variable-density recording were quite similar.

MR. KELLOGG: There are, of course, qualifications to such a statement. The mechanical part of it, namely, getting the shutter out of the way, is, I think, essentially the same kind of problem in both systems.

MR. LORANCE: It is. Yet I feel that it is essential to recognize the minor differences. We probably have recognized them in the past but perhaps may now be overlooking them. For instance, in variable-area recording, to get 10-db noise-reduction we must bias to one-tenth the normal width. In variable-density recording, to get 10-db noise-reduction we must bias to about three-tenths the normal exposure. This means that only about 10 per cent of the total modulation can be accommodated in a variable-area system before clipping begins; while in a variable-density system with 10-db noise reduction, about 30 per cent of the total modulation can be accommodated before clipping begins.

Filtering probably resolves itself to much the same thing in both systems, although the history is such that we may be inclined to overlook the fact. A great deal of variable-density recording has been done with the light-valve. All the filtering must be in the noise-reduction circuits, because the ribbons respond to such a wide frequency range. But in variable-area recording the shutter mechanism probably introduces a noticeable amount of filtering. When we discuss filtering we should take into consideration the overall combination of the noise-reduction device itself, as well as the circuits which feed it.

MR. KELLOGG: I do not disagree with anything that Mr. Lorange has said. If I had had time, I should have elaborated on that subject. I hope I have made it clear in the paper that I am thinking of the ideal system as one that, if it does use a shutter, will use one with minimum inertia. I should like to reduce the filtering to one stage, and not have a second stage occurring in the shutter inertia. Actually, at present, shutter inertia plays a small part of the total timing. I look forward to the availability of still faster shutters, and I think that it will be possible, regardless of the fast shutters, so to reduce the ripple at its source that we shall not need the filtering we now get from the shutter inertia.

## SOME LABORATORY PROBLEMS IN PROCESSING 16-MM BLACK-AND-WHITE AND COLOR-FILMS\*

WM. H. OFFENHAUSER, JR.\*\*

*Summary.*—The duplication of 16-mm films involves many relatively intricate problems not encountered in the laboratory processing of 35-mm sound-films. These problems have given rise to procedures and apparatus radically different from those in use in 35-mm.

The two major differences that are especially significant are (1) the use of reversal for original films; (2) the existence of but one row of sprocket-holes on the 16-mm sound-film.

It is interesting to note that all our present standards in 16-mm blindly assume the negative-positive method of operation, ignoring entirely the reversal and Kodachrome. At the present time even the emulsion position of the 16-mm film is standardized on the basis of a 35-mm sound negative and 35-mm picture negative as originals. As a result, our 16-mm dimensions so derived from 35-mm are inconsistent with the projector dimensions at present in use, and inconsistent with the pressing needs arising from the direct 16-mm field.

Much of the difficulty arises from the rather obvious lack of concern displayed by the 35-mm entertainment industry and the very rapid simultaneous growth of direct 16-mm in educational and industrial applications especially in connection with the duplication of sound on Kodachrome.

Some of the special processes and special apparatus features involved are described which have made possible workable solutions to the problems involved.

It is the avowed purpose of standardization to crystalize practice in order to make for better uniformity and greater reliability of product. This has been no less true of 16-mm motion picture practice than it has in any of the broader fields of application of technology.

It has been said that the most standard thing in the world is a piece of 35-mm motion picture film; this film will perform in any 35-mm projector regardless of where either film or projector may be made. To a slightly lesser degree the same may be said to be true of 16-mm film and 16-mm projectors. Despite the fact that the differences between the two cases may be small, they are extremely important, and they will explain why, in many cases, prints made in 35-mm in accordance with 35-mm practices may accomplish what is

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desired, while prints made in 16-mm in accordance with 35-mm practices miserably fail. There must be an understanding of the medium, its advantages, and its limitations before best use can be made of it. One of the purposes of this paper is to point out what some of the differences are between 35-mm practice and 16-mm practice in the production of 16-mm films, how these differences arise, and how the problems which result are solved in a practicable manner.

It may seem trite to state the postulate that a 16-mm film should perform satisfactorily in a 16-mm projector. When this statement is rewritten in different form, it acquires much significance. We may say that, when a 16-mm film made in accordance with what is considered good technical practice does *not* perform with maximum satisfaction upon a projector made in accordance with current standards and good technical practice, something is wrong with the practice, with the standards, or with both.

Our Society has established recommended practices and standards in connection with 16-mm film and equipment, and these practices and standards have been discussed in some detail in previous papers.<sup>1</sup> "A Criticism of the Proposed Standard for 16-Mm Sound-Film" was an attempt to compromise in a practicable way among the past, present, and future. It has been used as a guide in making decisions on how the problems, that arise may be solved in a logical and practicable manner.

Let us first look at a piece of 35-mm film and a piece of 16-mm film and compare them. The 35-mm film is more than twice as wide as the 16-mm. The 35-mm sound-film (and the silent as well) has eight sprocket-holes per frame, four on each side; the 16-mm sound-film has only one.

Let us next look at the projectors in which these films are run. In the 35-mm projector, the emulsion of the film faces the light, while in the 16-mm projector, the emulsion faces the screen and is *away* from the light. While we are concerned with the light we might as well find out what quality of light is used—in the 35-mm projector the light-source is usually an arc with much blue light, while in the 16-mm projector, the light-source is usually an incandescent lamp which is much more yellow. We might also mention while we are discussing the projector in relation to the film that it is not at all unusual for 16-mm projectors to be operated with appreciably higher magnification than 35-mm projectors. One case comes to mind in which both 35-mm and 16-mm pictures are projected on the same screen in

a theater—the 16-mm magnification is more than twice as great in this case. For our purpose here, the matter of film speed of 90 feet per minute for 35-mm and 36 feet per minute for 16-mm is not of great importance.

Let us now return to a practical production and laboratory problem: a 16-mm film is needed that is to be part black-and-white and part Kodachrome, and, of course, the film is to be made with sound.

Taking the black-and white part of the problem first, we would say, offhand, that it should not be difficult; all that is necessary is to take our picture on 35-mm and everything will turn out all right. We take our picture and record our sound—and then send the film to the laboratory. At this point the problem begins; the laboratory, usually without special instructions, observes that the film is 35-mm, develops it accordingly, and returns it. Picture is ordinarily developed to a gamma of about 0.65 to 0.75, since when such a negative is contact-printed to a gamma of 2.4 or so, the resulting picture is considered pleasing when projected on a 35-mm projector. If the sound is linear-recorded variable-density, the negative is developed to a gamma of about 0.45 or so, since when it is so developed it produces the proper overall print gamma of about unity when 35-mm contact-printed. It has not been at all uncommon for both picture negative gamma and track negative gamma to exceed these “average” figures appreciably.

When the negatives are edited, they are then turned over to a laboratory for printing (often by a technically uninitiated client) and the job of attempting to make good release prints begins. Everything seems in good order; the emulsion position of the prints will be in accordance with the standard, and the negatives are made in accordance with good commercial practice; yet the prints will be washed out and hard, and the sound unnecessarily badly distorted. A rather well known important fact has been ignored: an optical printer increases contrast, and nowhere has this been taken into account. The client has been led to believe that all 16-mm prints are bad, and since in most cases he does not know the difference and has never been shown, he continues to be satisfied with print after print of horse-and-buggy quality. At these laboratories, we try to compensate for this by obtaining positive film of lower gamma for reduction printing than that used for contact printing. In one extreme case we have had to go so far as to develop positive prints in a negative bath!

The trend today is in the direction of high-quality fine-grain films;

the usual positive emulsions of this type are of slightly higher gamma (or contrast) than regular positive emulsions. Thus if the present 35-mm practice is continued and 16-mm fine-grain high-quality higher-contrast films come into wider use, as they are now, our improved fine-grain print will not improve results to the great degree possible and desirable without some material alteration of the handling of the original 35-mm negatives. In the long run it will be far less expensive to reduce the original negative gammas and thus allow for the reduction printer and film contrast increase than to print all the 16-mm prints on some such low-gamma stock as a duplicating type or to make some other special provision more costly than regular print development.

At this point, another suggestion may be in order in connection with reduction prints from 35-mm with variable-density tracks. In entirely too many cases, there is no rhyme or reason in the relationship of the picture negative gamma to the track negative gamma. It must be remembered that *both* are to be used in making the combined print—and that when a combined print is made the picture and the track must go through the same developer. The right hand must know what the left hand is doing.

The case of the 35-mm picture negative in combination with the 35-mm variable-area sound-track raises other questions, not the least important of which is the fact that most reduction track printers are of the fixed reduction-ratio type, and many are not too well adjusted, and therefore the 16-mm prints must be carefully watched in the case of even the good 76-mil 35-mm sound-tracks to make certain that they will satisfactorily project on a 16-mm projector. The width of the track is 76 mils; the reduction ratio is fixed at about 7 to 6; and from there on, let the chips fall where they may—and they do.

A short while ago, one of our customers brought in a 16-mm reduction print made in one of the large New York 35-mm laboratories and wanted to know why it was "sour." The reason, upon investigation, was quite simple—the sound-track on the 16-mm print was 0.013 inch out of position. In our Standards Committee we are much worried about placement errors in printing of 0.002 inch. On the whole, West Coast laboratories are less concerned with 16-mm prints, with the result that comparable cases are not less uncommon.

Let us again return to our hypothetical 16-mm film and find further alternatives for our black-and-white section. We can photograph on



16-mm negative—record our sound as a 16-mm negative—and make a combined 16-mm contact print of our picture. Good quality is possible; there are no optical printing steps to accentuate scratch and cinch marks and to increase the harshness of the picture. We have, however, one matter that we must watch in connection with our sound record—it must be made to run in the same manner as the picture negative; otherwise the sound-track, if contact printed, must either be printed backward or through the base. In the first case of error the result is useless and in the second case the result is noisy and almost unintelligible. In neither case of error is it commercial. Rule No. 1 in purchasing a 16-mm sound recorder should therefore be: use a machine that will run equally well in *either* direction without any mechanical or other changes necessary to effect the change-over from operation in one direction to operation in the other direction.

If our direct 16-mm negative is contact printed, the emulsion position of the 16-mm print is similar to the emulsion position of a 35-mm print; it would be correct for 35-mm and “wrong” for 16-mm.

Our 16-mm black-and-white film may be made with a 16-mm reversal original from which a duplicate negative is made, which dupe negative, together with a sound negative, is used to make a contact print. Both picture quality and sound quality in a print from such a combination may be made superior to picture and sound quality obtained by any other means. Some data concerning the picture phase of this method have been published in the JOURNAL by J. A. Maurer.<sup>2</sup> In this case the emulsion position is correct (assuming contact printing throughout). By optical printing from the reversal to dupe negative, the emulsion position may be made “wrong.”

Let us now go to the Kodachrome section of our hypothetical reel. Kodachrome is a reversal film and therefore the emulsion position is “standard”—away from the projection lamp and toward the screen. If we want a Kodachrome duplicate, it is best made by contact printing rather than by optical printing; optical printing would not only further increase the Kodachrome contrast but would also greatly accentuate all the scratch, abrasion, and cinch marks on the original film. When Kodachrome is contact-printed, the emulsion position, as in the case of negative, is “wrong”—in projection the emulsion faces the light; also in the case of negative-positive on 16-mm the black-and-white print is also “wrong.” The two may then be spliced together and when they are run, they will project *without change in focus* of either picture or sound-track, throughout the reel.

Another practical problem that arises relates to the printer aperture for Kodachrome. Kodachrome is essentially a reversal film and a Kodachrome duplicate is therefore equivalent, in a sense, to a duplicate reversal. If a duplicate is to be printed, it is obvious that the picture printer aperture should be *smaller* than the camera aperture if a white frame line around the picture is to be avoided. The projector aperture should be smaller than either the printer aperture or the camera aperture if both black or white frame lines are to be avoided in projection. The sizes of these apertures must be carefully studied, as it is not unusual for 16-mm sound projectors to have a picture aperture far smaller than standard which, with composition intended for standard aperture projectors, results in the rather annoying cutting off of heads and feet. With apertures related in this manner instead of in the customary negative-positive manner, appreciably greater camera, printer, and projector accuracy is required.

The next matter for consideration is the sound. We can use either a 16-mm original or a 35-mm original, either variable-density or variable-area. In 16-mm the originals may either be developed and printed or an original may be recorded which is reversed either chemically or optically—quite a variety of types when we compare this with 35-mm.

We can set down several general rules for printing sound on Kodachrome:

- (1) The printing aperture should be *smaller* than the positive image from which printing is accomplished.
- (2) If a variable-area negative is used, the printing aperture should be *larger* than the width of the negative record.
- (3) The projector aperture should be *wider* than the 16-mm recorder aperture (or reduced 35-mm aperture); yet *smaller* than the aperture used for printing the black-and-white positive.

Several comments should be made at this point concerning variable-density linear recordings. With regard to the quality of sound, a good general rule of thumb is to duplicate from a positive which in itself has minimum distortion. In the case of variable-density 35-mm originals, it should be obvious that a 35-mm negative of gamma 0.45 which will contact-print in the usual way to a gamma of 2.4 will have an excessive gamma product when optically reduced from that 35-mm positive to Kodachrome; the increase in printer factor of the optical sound-printer over the contact printer is one possible cause. Our experience indicates that there are others, as we have found that

a special low-gamma 16-mm reduction-track positive seems to correct not only the Kodachrome duplicating step but also for other steps as well. The track positive gamma is so low that the distortion produced by a print of conventional gamma is best described in some cases as "terrific."

The case for 35-mm variable-area negative tracks has the usual complications with regard to dimensions and envelope effect. If the 35-mm negative is optically reduced to a 16-mm positive, as we do at this Laboratory, and this 16-mm print used for the Kodachrome duplicate (as in the variable-density case above), only the 16-mm track printer needs to be masked to print to Kodachrome from any conventional original negative—either 16-mm or 35-mm. At this point, we must again warn against the not uncommon uncertain sound-track, the uncertain 7 to 6 reduction ratio, and its uncertain result.

The optical reduction of 35-mm sound negatives to 16-mm smooths one other difficult problem: that of synchronizing the picture and sound. In 35-mm the sound is advanced 20 frames; in 16-mm the sound is advanced 26 frames. At our laboratories all 16-mm films are marked even (this is easier for cutting), and the advancing is done in the printing room on the printing machine. In this manner we avoid synchronizing-mark confusion, since the question of whether films are advanced 20 frames as in 35-mm or 26 frames as in 16-mm does not arise.

With regard to other sorts of originals for sound such as toe-recorded 16-mm tracks or toe-recorded 35-mm variable-density tracks, it can be said that they are very few in number, and for the most part the quality is quite poor due to the fact that the Kodachrome duplicating step is usually ignored, and for other reasons not related to Kodachrome. Variable-area master positives in either 35-mm or 16-mm have not put in an appearance; some misguided attempts by the technically misinformed have been made to save the cost of a track positive, but the sound proves so poor as a result, and the procedure so costly in the long run, that such attempts die out very quickly, usually after the first attempt.

Let us return again to our production and laboratory problem: the film, part black-and-white and part Kodachrome. If we want acceptable picture quality, we are forced to contact-print the Kodachrome. The sound is no problem; we print our sound on a 16-mm optical 1 to 1 sound-printer. With this printer it is possible to focus on either side of the film merely by turning a focusing ring as far as it



will go in the proper direction. Our combined duplicate, though good in quality, is "wrong"; it is non-standard.

If we are to splice black-and-white together with Kodachrome in the same reel, it is necessary to make our black-and-white "wrong" or non-standard as well; in this manner we avoid the necessity of refocusing our projector in the middle of the reel. Progressive projector manufacturers long ago recognized the importance of "wrong" or non-standard films, and made provision for focusing the sound optics of the projector on either side of the film. Thus with a "wrong" projector and a "wrong" film, we obtain best results with our problem picture.

If we return now to our premise that the desideratum is that a 16-mm film projects best in a 16-mm projector, it would seem, in this case at least, that the avowed purpose of our 16-mm standard is defeated under the present standard. Without qualification, it is strongly urged that the 16-mm standard for the emulsion position be made to conform to the 35-mm standard in projection—that is, toward the light. It is also recommended that, if the 16-mm standard is to remain tied to 35-mm, some analysis of the 35-mm problem in relation to 16-mm be made by those interested in the 35-mm production of 16-mm films in the light of the aforementioned problems. In the absence of such an analysis and recommendation and in consideration of the complexity of the 16-mm problem, a complete divorce of 16-mm from 35-mm is recommended *via* a specific optical reduction ratio or other proportional dimension relationship. It is only in this manner that we can right a growing "wrong."

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## PRODUCTION-QUALITY SOUND WITH SINGLE-SYSTEM PORTABLE EQUIPMENT\*

D. Y. BRADSHAW\*\*

*Summary.*—*The March of Time* requires equipment of great portability and simplicity of operation, yet retaining good quality. By using Class B push-pull, variable-area recording, a complete noise-reduction sound system weighing fifty pounds was obtained. This single system was used in production of the feature picture *The Ramparts We Watch*. Problems arise from (1) recording on panchromatic negative, (2) lack of control over negative processing, (3) instability of recording unit caused by rough use of camera on which it is mounted, and (4) distortion due to lateral track shift. Means for overcoming these handicaps sufficiently have been found. Single system can be used without great sacrifice in quality, where time and space are factors.

The nature of *March of Time* work requires light-weight equipment of extreme portability and simplicity of operation. The equipment must be such that it can be moved into position and set up for a shot in ten minutes or less. Most scenes are made on location—in offices of government officials, in coal mines, in aeroplanes, in battleship turrets, at political meetings; in short, on typical newsreel locations, where both time and working space are limited. However, better than usual newsreel quality of sound is essential.

It is reasonably simple to construct a light-weight amplifier with a good response characteristic. To retain some degree of versatility and still keep bulk and weight at a minimum, a novel but simple input layout was devised in the amplifier design. A two-position mixer is used with a three-microphone input. One input line feeds directly through one mixer, while the other two lines with a selector switch between them feed the second mixer. As a result an amplifier of small dimensions was obtained, having varied capabilities but weighing only forty pounds, complete with batteries sufficient for twenty thousand feet of recording. Using small cables and light-weight microphones of the highest quality available, the entire equipment with the exception of the recording unit obviously can be made

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\*\* *March of Time*, New York, N. Y.

adequately portable. For the March of Time, the weight and bulk of a separate recorder were out of the question. Also, any heavy, complex, single-system camera was equally unsuitable, as was any additional equipment for noise reduction. Hence a standard newsreel camera, recording on the main sprocket, was selected.

Request was made for the development by RCA of an optical system to give an ultraviolet, Class *B*, noise-reduction sound-track. It was required that this unit be compact and light in weight, and adapted to the newsreel camera selected. To aid in keeping the unit compact, the frequency response upper specification was reduced to 6500 cps. It was believed that a loss at frequencies above 6500 would not noticeably affect speech quality and would not render any field music recording unusable. The galvanometer unit, more than meeting these requirements, adds little bulk to the camera and approximately five pounds to its weight. Thus, without the necessity for additional noise-reduction equipment, or for a double-system recorder, a small, complete, good-quality sound system, weighing approximately fifty pounds, was obtained. The entire sound outfit is carried and operated by one man, eliminating the necessity for a large truck or a recording room, with the accompanying cables and intercommunicating systems.

For the feature picture *The Ramparts We Watch*, the same requirements of lightness and portability of equipment existed. The producers desired to inject an authenticity and feeling of reality into their scenes by working on actual locations so far as possible, and to eliminate unnecessary expenditure for sets and equipment in achieving that reality. The troublesome points in the single system had been sufficiently ironed out that it was believed a satisfactory job of recording the first feature-length picture could be done.

The principal difficulties with the system are (1) recording on panchromatic negative stock, (2) lack of any control over processing the negative sound-track, (3) a tendency toward instability of the sound unit on the camera, and (4) susceptibility of the push-pull track to distortion due to lateral shift in track position. Means have been found for adequately overcoming these troubles.

In the first place, variable-area recording on negative stock means reduction of signal-to-noise ratio, because it is obvious that exposure of the negative track can not be made very great before lack of definition becomes serious. However, it was found that with Class *B* track, this situation could be sufficiently overcome. By exposing



the track to give a negative density of 1.2 to 1.3 when the film is given normal picture development, and printing to a density of 1.3, good contrast is obtained with only slight loss at high frequencies. This is due in great part to an inherent characteristic of the Class *B*, variable-area track. Each half of the wave is recorded on an entirely independent track, so that both the maximum and minimum points on the original wave are exposed on the negative at points on a convex curve, with a half-cycle length of unmodulated track separating the adjacent exposed areas. In the case of other variable-area tracks, the minimum points occur where the exposed section is concave, with no separation between adjacent exposed areas. Although the filling in is reduced to a great extent with a double-system set-up, using positive sound stock, the loss of definition when recording on negative stock is objectionable. However, the separation obtained with Class *B* maintains the high-frequency response to a surprising degree.

Because of limited facilities and time, no attempt is made to check the negative gamma. Even if the negative gamma were known, the wide variations in negative picture development would make useless any attempt to obtain overall gamma of unity. However, the effect of variation in processing can be greatly offset. Cases of extreme overdevelopment have been encountered, but have been corrected by an increase in print density. The same treatment has been used to correct for overexposed tracks. The worst case occurred when a cameraman switched to a faster film at the last minute before photographing and recording Fred Waring's orchestra for a commercial release. The soundman was not notified of the change and exposed the track for the usual panchromatic film. When a print of the track of density 1.2 was reproduced, the distortion was intolerable. However, by printing to a density of 1.5, the roughness disappeared from the track, and the resultant increased attenuation at high frequencies was not greatly objectionable.

When the tracks are underdeveloped, the prints are made slightly on the light side and good results are obtained with some sacrifice of signal-to-noise ratio. The worst condition encountered involved a negative track density of 0.7, from which a print of density 1.05 was made. This particular recording was used in one of the scenes of *The Ramparts We Watch* and was not objectionable.

A newsreel camera is not the ideal location for a sound modulator. Packed and unpacked several times a day, transported over the

country in the trunk of a camera car, carried over the cameraman's shoulder, operated at all angles—the rough use of the camera results in abuse of the galvanometer unit as well as of the sprockets and guide rollers in the camera. Nevertheless, a simple correction has been found for each difficulty encountered. Adjustments usually can be made after inspection of the equipment on location, but on occasion equipment failure has produced unique problems. In one instance, the lamp filament sagged in the middle of a long sequence. The result was a normally exposed negative on one side of the push-pull track while the other part was badly underexposed. Densities were 1.2 and 0.7. The speech from the reproduced print was found to be unintelligible. However, a simple adjustment of the balance of photoelectric cell voltages on the reproducer compensated for the unbalanced track and a satisfactory reproduction resulted.

Use of a newsreel camera without adequate provisions for insuring a fixed lateral position for the film results in a variation from scene to scene of as much as 5 mils. An attempt to align the film with rollers resulted in buckling the film as it left the intermittent sprocket. As the present problem is much more pronounced in printer variation, the purely mechanical solution of film position in the camera has not been attempted as yet. In an extreme case, a properly aligned negative track has been printed fifteen mils out of position, though the error, when present, does not generally exceed ten mils. The March of Time staff works to a deadline, without exception, and time seldom exists for reprinting displaced tracks. Obviously, a push-pull track is more susceptible to distortion from this cause than is a standard track. It has been found that the displacement must be enough to take at least two mils off the maximum peaks, to give noticeable speech distortion. Only one side of each half of the track is affected, of course. To overcome the situation in practice, some concessions are necessary. The recording is made at a maximum peak modulation of 80 per cent instead of 100 per cent. This means a latitude in track position of four mils on each side of each half-track. Hence the camera and printer must introduce an error of more than six mils to cause appreciable square-topping of the wave. The separation between the two parts of the Class *B* track is six mils. Any error in excess of ten mils becomes exceedingly serious, as the half-cycle peaks on one part of the track are then scanned on the other part, 180 degrees out of phase. When such a case exists, and no time is conveniently available for a reprint, it is a simple matter to move the

push-pull head on the reproducer an amount equal to the displacement. By setting the scanning so as barely to miss the sprockets, a satisfactory re-recording has been made from the extreme case of fifteen mils' displacement. Use of a dependable printer and camera will eliminate the problem of lateral shift entirely.

In ninety per cent of March of Time work, no trouble has been encountered and no corrections have been necessary. However, the single-system unit is susceptible to these difficulties which have been adequately overcome when they have appeared. Application of these occasional corrections is the only penalty for the use of a very portable, inexpensive, easily operated sound system. It is not suggested that the industry discard the comparatively cumbersome and expensive double-system equipment and the additional personnel required to operate and maintain it. Certainly such equipment is necessary to obtain the present limit of high-quality sound. Where time and room are factors, however, the single system can be used without great sacrifice in quality.



## THE PHOTOGRAPHIC ASPECTS OF TELEVISION OPERATIONS\*

HARRY R. LUBCKE\*\*

*Summary.*—Television utilizes certain elements of operative photography. In live-subject presentations these include composition, focus, contrast range, intra-image contrast of one object from another, dolly shots, panning, and certain aspects of lighting.

*In television, operative maneuvers must be quickly and smoothly executed. The camera in question may be supplying the outgoing image at the time in question, or, if not, it should rapidly be made available for change in camera angle on the program.*

*The equipment and technic evolved at W6XAO to meet these requirements during several years of telecasting are described.*

Television utilizes certain elements of operative photography. The television camera is maneuvered like a motion picture camera, only more intensively so. In studio cinematography opportunity is afforded to pause between sequences in the action, to check camera angles, composition, focus, lighting, and to predetermine the next pan or dolly shot. In television the action is continuous. Although two or three cameras simultaneously televise a scene, each from a different angle, it is necessary that each follow the action most of the time, thereby to be available to carry the outgoing picture at the election of the television producer. In this respect the cameraman's function is similar to that in newsreel cinematography, where the action must be followed and composition, focus, and other operative adjustments maintained almost subconsciously.

In considering apparatus, there are two major differences in construction and operation depending upon whether the focusing is adjusted by the cameraman or remotely adjusted by a television engineer who views a monitor image. There are three minor differences, relating to the type of viewfinder, whether it is a duplicate of the camera tube optical system, whether the camera tube image is viewed by mirror reflection, or whether a separate viewfinder is utilized,

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\*\* Don Lee Broadcasting System, Los Angeles, Calif.

either of the cinematographic type or of the frame and peephole type.

In operations it can be said that each of the above possesses advantages and disadvantages.

It can also be said that a trained crew can produce satisfactory television programs with any of the apparatus mentioned. The operative cameraman is always provided with head-phones and information transmitted thereover serves to bridge the shortcomings of either apparatus or personnel. Specifically, the cameraman may be warned of an impending change in location of the action, or instructed to follow this character while allowing another to pass from his field of view. Faults in composition or other image characteristics are at once relayed to him.

Rehearsal is the "great polisher" which contributes to the smoothness of the show. Rehearsals increase the expense of operations, however, and in days of non-commercial (non-income) television a fine balance is maintained between rehearsal time, skill of the crew, and the quality of the result. At times, a happy combination indicates the perfection of future television productions; at other times, inescapable accidents give a momentary result which cries for that saving grace of cinematography, the "retake," although this is impossible for obvious reasons. One faculty created by a skilled crew is the ability to gloss over errors or mistakes. An attentive producer eliminates faulty camera operation by shifting instantaneously to another camera. A fade covers a multitude of sins. It is an inspiration to watch emergency departures from the script skillfully handled by a production crew, resulting in a smooth performance to all save the few who knew what should have been.

This emphasis on the personnel aspect of television operations has been impressed upon us at *W6XAO* by years of daily telecasts. Apparatus is only part. The welding of apparatus and personnel into an operative whole is the important thing. Precision gained through apparatus complexity from an *operative standpoint* is to be decried rather than to be sought after.

To return to the apparatus and the major differences in construction; there are advantages to remote focusing. The cameraman is relieved of a duty and the focus adjustment is made utilizing an indicator which counts most, the actual television image. However, careful attention to focusing must be given by the engineer or the action will "get ahead of him." Also, such focusing requires one more man in the video booth, increasing personnel costs.

The duplicate optical system viewfinder is usually used with cameraman focusing and is quite satisfactory, only vertical parallax and cost and weight of the camera being adverse factors.

The mirror-viewing camera-tube-image viewfinder has no parallax, but tends to give an image too dim for consistent accuracy of focusing. Present technic uses an aperture from  $f/3.5$  to  $f/8$ . It is obviously ac-



FIG. 1. The mirror-viewing camera-tube-image viewfinder. The cameraman is viewing the image on the photoelectric plate, with right hand on the focusing adjustment on the farther side of the camera. The left hand is used for panning and tilting as shown. The scene is a close-up. The exaggerated under-eye make-up is no longer used.

curate in determining composition, even on close-ups, where the separate type of finder encounters difficulty. A camera of this type, with cameraman focusing, is shown in Fig. 1.

The usual cinematographic viewfinder has been tried in our operations but found unsuitable unless provided with automatic parallax correction.

The peep-hole and wire-frame type of viewfinder has been used considerably with remote focusing. This has proved reasonably satis-



factory with an adjustment technic as follows. Prior to the performance the cameraman checks the field of view of his finder with that actually appearing on the monitor image of the engineer. This is aligned by adjusting the sides of the finder frame until substantial coincidence is secured. Two pairs of side markers are used in the type of finder which is located at the side of the camera. The markers delineating a line of sight more nearly parallel to the camera tube optical axis is used for long shots, and the markers converging



FIG. 2. Peep-hole and frame type viewfinder. The photo shows a spring type adapted to work against a cam on the lens housing for automatic parallax correction. The cameraman stands closer to the peep-hole in usual operation.

toward the axis for close-ups. The shift from one group to the other is made subconsciously by the cameraman after a few hours' training. It is possible to include automatic parallax correction in a finder of this type, a cam operating against the motion of the lens mount automatically shifting the side markers, as shown in Fig. 2. These arrangements have largely been developed by our chief cameraman, Dwight Warren.

Other aspects of operative camera work include dolly shots and panning. These are usually indicated on the script and are universally called for by the producer viewing the outgoing image. The

camera crew carries out the instructions given to both the operative cameraman and the studio producer. Experience largely determines the necessary extent of these movements, and the result is guided to satisfaction by auxiliary commands from the producer to the effect of "more" or "hold that." as the case may be.

Still other aspects of television "photography" comprise contrast range, intra-image contrast of one object from another, and the effect of lighting, make-up, costumes, and properties.

The contrast of the image is adjustable electrically within certain optical limits. The lighting must be sufficient to produce optimum image brightness on the photoelectric surface of the camera tube. If an excess is available, as in outdoor pick-ups in sunlight, the condition is easily and happily remedied by closing the aperture. This gives relatively great depth of focus and often a discernible increase in image quality because of improved lens performance. Within the optical limits, camera tube beam current and amplifier gain determine the contrast. This is usually adjusted by the television engineer to "fill the pedestal"; that is, to utilize the full electrical waveform characteristic from the value representing black to the value representing full white; but not further, which will result in "cutting off the whites," "cutting off the blacks," or both, and is equivalent to over or underexposure in photography.

Intra-image contrast is a matter to be determined by rehearsal tests or to be provided for by prior experience. Almost any scene will televise intelligibly; but as in photography, the striking symphonies of light and shade which characterize the work of the expert must be planned in deliberate detail. The essential factor is the tone rendition of the colors and shades of everything that is in the scene. The color response of the usual camera tube is roughly panchromatic with overemphasis in the red. The spectral response of the incident light is a factor. At *W6XAO* we have found that white light of high-temperature tungsten lamps is preferable to the yellow-red light of ordinary lamps. Panchromatic make-up with violet-hued lipstick is satisfactory. "Indian pottery tan" in all its tones appears to be a uniquely satisfactory color, as has been previously reported.<sup>1</sup> Properties are easily assembled which prior tests have shown to be satisfactory with the studio technic and characteristics in use at a given time.

The latter is an important aspect of production operations. It is a combination of electrical circuit behavior all the way from camera

tube to average receiver screen, combined with camera optical and photoelectric properties in addition to lighting, make-up, costume, and property technics.<sup>2,3</sup>

Our work has shown that a substantial change in any of these factors, at times unintentional, may require compensating changes in the technic of one or more of the others. One of the compensations of present-day television production is that these changes can be made. Another is the preception of the future, with the work of today recognized as merely a rough approximation of what can be done in the future when greater control will be had over factors now identified but not yet susceptible to accurate control.

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## NEW MOTION PICTURE APPARATUS

*During the Conventions of the Society, symposiums on new motion picture apparatus are held, in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.*

### A NEW TREATMENT FOR THE PREVENTION OF FILM ABRASION AND OIL MOTTLE\*

R. H. TALBOT\*\*

General film appearance and picture quality have long been major problems with the motion picture industry. Of the numerous factors influencing screen quality, this paper will deal with two, namely, film abrasion and oil mottle.

The former of these, film abrasion, has been the object of much research leading to a large number of patented processes, some of which are in use in the trade. These processes, in general, leave something to be desired, either in effectiveness or in price, frequently in both. They depend for their effectiveness on the principle that the treated surfaces will be more resistant to abrasion than those not similarly treated. Whereas this may be true in some cases, the fact remains that no practical film surface has been found which will resist abrasion indefinitely. Therefore, when these treated surfaces become abraded, they present the same problem as do any other scratched films.

*Protection of Film from Abrasion.*—Experiments have been conducted in this laboratory and in the field with a new type of film treatment based on a new principle. The aim has been to devise a lacquer which can be applied easily and removed easily. This lacquer, when applied to both sides of the film, becomes scratched just as the film surfaces would have been scratched by any sharp points coming in contact with it. If the thickness is correct, however, normal scratches do not go through the lacquer layer into the film. Therefore, on removal and renewal of the lacquer, the film is found to be in as good condition as when new.

As for the lacquer itself, it was necessary that it fulfill certain definite requirements. These requirements were:

- (1) Its manner of application must be simple, requiring practically no special equipment.
- (2) Its rate of application must be comparable to average processing speeds.

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\* Presented at the 1940 Fall Meeting at Hollywood, Calif., October 21-24, 1940; received November 25, 1940.

\*\* Eastman Kodak Company, Rochester, N. Y.

(3) It must be easily removable without the aid of solvents or special equipment.

(4) It should be applicable to both sides of nitrate and safety films without any deleterious effect upon physical properties, such as curl, flexibility, moisture absorption, *etc.*

(5) It must dry rapidly to give a smooth coating of glossy appearance. The reason why a glossy surface is essential will be discussed later.

(6) It should make the films fingerprint-proof.

Let us now see how the Eastman Protective Film Lacquer fulfills these requirements.

*Application of Lacquer by Wick Method.*—Fig. 1 shows the simplest manner by which this lacquer may be applied to either 16 or 35-mm films. In this method

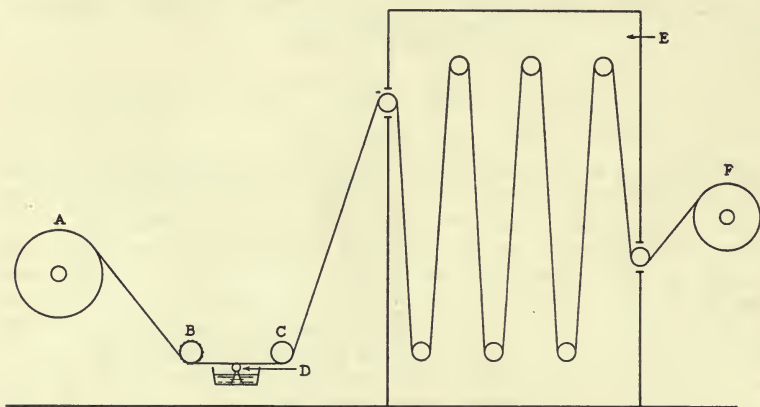


FIG. 1. Apparatus for applying Eastman Protective Film Lacquer to the entire surface of 16 or 35-mm film by means of a wick: (A) stock roll; (B) drive sprocket; (C) idle roll; (D) plush wick and holder; (E) drying cabinet; (F) take-up roll.

the entire width of film, perforated area included, is coated with the lacquer. This is accomplished by drawing the film from the stock roll over a strip of plush wet with the lacquer and thence into the drying cabinet and onto the take-up roll. In the case of this plush wick method, the thickness of the coating will depend somewhat upon the speed of application. At high speeds the coating may become quite thin due to the inability of the wick to absorb liquid rapidly enough. If the coating becomes too thin the covering power of the lacquer will be impaired and proper protection against abrasion will not be provided. It is suggested that this method be used only for speeds of application of 50 feet per minute or less.

Fig. 2 shows a close-up of the wick and lacquer pan. A suitable wick may easily be constructed by clipping a strip of plush around a glass rod by means of a wire stapler.

Fig. 3 shows a plush or felt-covered roll which may be used in place of the stationary wick. The roll is driven slowly in a direction opposite to that of the film travel. In this case the thickness of the coating is independent of the film speed,

as the speed of the roller wick may be increased in the same order as the film speed is raised. The speed of application, therefore, will be limited only by air cabinet capacity, *etc.* Applications should be satisfactorily made at speeds as high as 150 feet per minute.

*Application of Lacquer by Bead Method.*—Fig. 4 shows the apparatus for applying the lacquer to the picture and sound-track area only of 35-mm film. In this method the film is wrapped tightly about the idle roll *D* and the lacquer is applied by means of an auxiliary roll *E* which revolves slowly in a pan of lacquer. This applicator roll *E* does not quite come in contact with the film in operation but at the beginning of the coating it is brought momentarily into contact with the film on the idle roll *D*, and then the two are separated slightly. The bead of liquid which forms between the film and the applicator roll is thereafter maintained and the coating is accomplished by this liquid bead and not by contact with the applicator roll. By this means a smooth layer of lacquer is applied onto the film from perforation to perforation. These edge lines are quite sharp and may be maintained to within about 0.002 inch from a straight line. This method, although

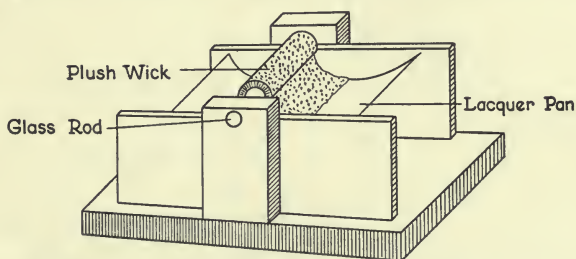


FIG. 2. Close-up of plush wick and lacquer pan.

more complicated than the wick method, gives coatings of greater thickness and better appearance. It is especially adaptable to negatives, duplicating negatives, master positives, and the like, since no lacquer reaches the perforated area and therefore can not cause trouble from the standpoint of dirt, positioning, *etc.* In the case of this bead method, the thickness of the coating is dependent not only on the relative speeds of the film and applicator roll but upon the distance between the applicator roll and the film. By this method lacquer has been continuously applied to 35-mm films at a speed of 150 feet per minute.

*Removal of Lacquer.*—The protective coating can be removed easily by immersion for one or two minutes in 1-per cent sodium carbonate at 65°F, followed by a clear water rinse. In practice, therefore, the coating can be removed easily and completely by passing the film through a machine similar to a processing machine in which the film is given a two-minute immersion in 1-per cent sodium carbonate followed by a clear water rinse (Fig. 5). In order to avoid the possibility of emulsion-stripping in this removal process, it is recommended that the sodium carbonate solution contain 1 per cent by volume of commercial formalin solution. This will prevent swelling of the emulsion and likewise minimize the possibility of emulsion-stripping on films which have not been hardened sufficiently in the original processing operation.



Fig. 6 illustrates the removal of the lacquer in a regular processing machine merely by the substitution of a neutral rinse for the customary acid stop bath following the developer.

*Effectiveness of Treatment.*—Thus the requirements in regard to simplicity of operation and speed of operation have been satisfied. Furthermore, comparison of coated and uncoated films both immediately after coating and after service in the field has shown that there has been no noticeable change in physical properties. In addition, fingerprints may be removed completely from the coated film by gentle wiping.

Films treated with this lacquer will be protected against all ordinary cinch marks and against the normal scratches found on most films which have been in service in the trade. It would be ridiculous, of course, to pretend that any lacquer of a thickness of 0.0001 inch could not be scratched through, if conditions are severe enough. Our experience, however, indicates that such scratches seldom occur in practice.

There is one other point in regard to this scratch-protective layer that should be mentioned. It has been pointed out that our aim was to apply a lacquer

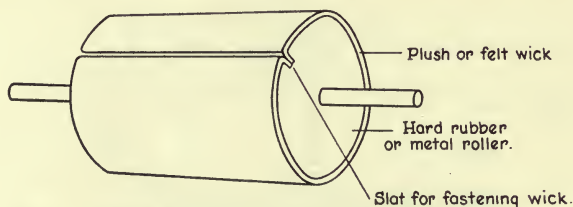


FIG. 3. Plush or felt-covered roll for continuous high-speed wick application of lacquer.

which would bear the scratches which would normally be found on the film. The question naturally arises, "To what extent does the coating itself become scratched? Does it scratch more or less readily than normal film surfaces?" This question can be answered at the present time only in the following way. Laboratory comparisons have indicated that the coated films have approximately the same scratch resistance as untreated films. However, without a single exception, the experience with these coated films in the field has indicated that they are definitely more resistant to abrasion than the uncoated checks. The ultimate answer to this question must be deferred until more practical information has been accumulated.

*Protection of Film from Oil Mottle.*—To this point we have been concerned with film abrasion. We will now consider the closely allied subject of oil mottle or, in other words, the continual flicker on the screen due to oil spots on the film. In the course of our study, it soon became apparent that flicker due to oil on the film was more detrimental to screen quality than was the occasional scratch. Scratches which are extremely prominent to the technical people of the industry nearly always go completely unnoticed by the average theater patron, due, no doubt, to absorbing interest in the story. On the other hand, flicker on the screen must be avoided by all means. Noticed or unnoticed, this mottle most surely has its

effect upon the eye and upon the fatigue of the spectator. Although no scientific proofs of this are available, I believe that the comments of the spectators who are allowed to see both clean film and oily film, one after the other, are sufficient indication of the increased pleasure in viewing the mottle-free film.

This question of oil on the film has not had the attention given to it which it deserves. Heretofore, it has not been thought of as an actual damage to the film as is the more conspicuous scratch. Furthermore, one has thought that if oil does get on the film it can be removed by cleaning. It is true that oil may be removed easily from a small area of film with a clean pad and fresh carbon tetrachloride, but it is quite another matter to clean an entire roll effectively without streaks, bloom, abrasion marks, *etc.* Thus it is that oil, which often gets on the film on its initial run, regardless of the quality of the house, usually stays there throughout the life of the film. Large sums of money are spent by film manufacturers, processing laboratories, and studios in order that the photographic quality of the

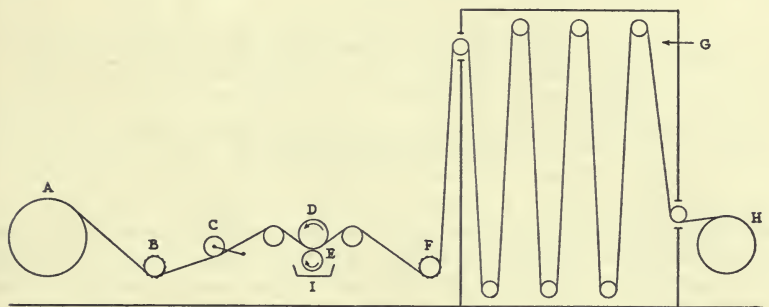


FIG. 4. Apparatus for applying protective film lacquer to the picture and sound-track area only of 35-mm film by means of a liquid bead: (A) stock roll; (B) drive sprocket; (C) float roll (oil-damped); (D) idle roll; (E) driven applicator roll; (F) drive sprocket; (G) drying cabinet; (H) take-up roll; (I) lacquer pan.

pictures may be maintained at the highest possible level, yet this oil mottle often nullifies completely the careful work which has been done on the picture to this point.

The reason why oil spots on film produce mottle is well understood. Each oil spot produces a glossy surface which permits more of the light from this area to be focused on the screen than from the neighboring unoiled surfaces.

The remedy, of course, is to make the whole surface glossy so that there will be no more light coming from the oily spots than from the rest of the surfaces. This lacquer accomplishes this to a remarkable degree. Although the trained eye can readily distinguish the oil, even on the lacquered film, the improvement is great enough so that most spectators would feel that the mottle is entirely eliminated.

*Results of Field Tests.*—For the evaluation of the effectiveness of this lacquer treatment under actual trade conditions, a feature picture was placed at our disposal by the Metro-Goldwyn-Mayer Company. A portion of this print was given the lacquer treatment at the time of release. The entire feature was then

put into service through the Buffalo Exchange of M-G-M. At intervals the print was brought to the laboratory for examination. This allowed a comparison to be made between the untreated sample and the lacquer-treated sample in respect

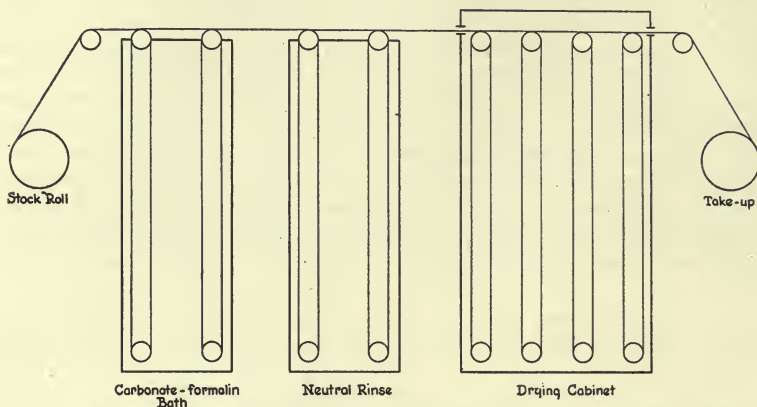


FIG. 5. Apparatus for removal of protective film lacquer by means of carbonate-formalin solution.

to abrasion and oil mottle. Screen tests of the two samples clearly indicated that the abrasion of the lacquered sample was considerably less than that of the untreated sample. Likewise even though there was the same amount of surface oil on both films, the mottle on the screen due to this oil on the treated film could

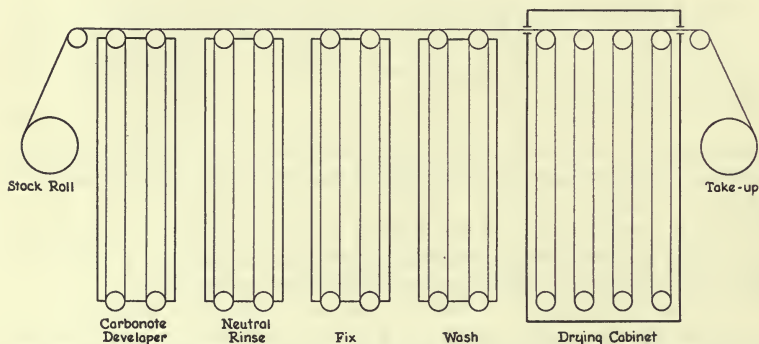


FIG. 6. Regular processing machine used to remove the protective film lacquer.

be detected only with difficulty, whereas that of the untreated sample was very pronounced.

When sufficient reduction of screen quality resulting from abrasion was noted on the treated samples, portions of them were retreated, *i. e.*, the original lacquer removed in carbonate solution and a fresh coating applied. Consequently that



portion of the print which was thus retreated from time to time retained "new print quality" throughout the 35 bookings or approximately 164 runs.

*Remarks.*—It should be mentioned that the solvents employed are similar in inflammability to ethyl alcohol, and therefore all electrical equipment such as light fittings, motors, switches, *etc.*, should be solvent-vapor-proof. Recirculation of the air in the cabinet is inadvisable. The exhaust vapors should be conducted outside the building. The solvents are similar to those used in quick-drying lacquers and finishes, and the same care should be exercised as when handling any inflammable volatile organic solvents.

*Acknowledgment.*—Acknowledgment is made to Mr. W. D. Kelly of Metro-Goldwyn-Mayer for the use of their prints for the preliminary field tests. Acknowledgment is likewise made to Mr. J. H. Spray of the Ace Film Laboratories, Brooklyn, for the practical information gained in his plant on the use of the lacquer during the past year on color-films as well as on black-and-white negatives and prints.

#### DISCUSSION

QUESTION: What is the cost of applying the lacquer?

\*MR. TALBOT: The cost of materials is about \$0.40 for each side for each 1000-ft roll. The labor cost will vary from almost nothing, if the lacquer is applied on the processing machine and no extra help is required to take care of it, up to \$0.50 or \$1.00 a roll if a special job is made of it and only a few rolls are treated.

QUESTION: Can the lacquer be applied to various types of color-film?

\*MR. TALBOT: The difficulty with the application to color-film is that most color processes utilize dyes which are soluble either in water or dilute sodium carbonate which makes the removal of the lacquer difficult. It has been used commercially for some time by the Ace Laboratories for coating their duplitized color-prints largely for the purpose of the elimination of oil mottle, although the scratch resistance of the lacquer itself is also a factor. The new universal lacquer can be removed by an alcohol treatment, although care must be used to avoid warping the film. Experiments are under way with this new type of lacquer and the use of isopropyl alcohol for its removal from Technicolor film.

The application and removal of the lacquer by carbonate solution is entirely satisfactory in the case of Kodachrome.

QUESTION: What is the cost of equipment for applying the lacquer?

\*MR. TALBOT: That depends entirely upon the set-up. It is to be assumed that any processing laboratory will have equipment available, such as the stock roll, drying cabinet, and rewind mechanisms; therefore, the only special equipment is the coating unit. The cost of this coating unit will depend on the method employed. If the simple wick method is employed for speeds of 50 feet per minute or less, the cost of the equipment will be but a few cents, *i. e.*, a strip of clean plush, a glass rod, and a lacquer pan. If the wick method is to be employed for speeds greater than 50 feet per minute, a plush-covered driven roll is necessary. The cost of this equipment will be the cost of a small motor plus the cost of a slotted roll for holding the plush. The cost of this roll should not exceed \$5.00.

For bead application the coating unit is somewhat more complicated and should be made with great precision, if the unit is to operate satisfactorily at high rates of

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\* Communicated.

speed. Detailed plans of such a unit are available from the Eastman Kodak Company upon request.

QUESTION: How many release prints could be made from a negative coated with this lacquer?

\*MR. TALBOT: The Ace Laboratories made 375 prints from a negative which had been coated on the emulsion surface with the protective film lacquer. It was not necessary to remove the lacquer from any reel during this printing. After the 375 prints were made the coating was removed and the negative appeared to be in just as good condition as before release printing began. Presumably the negative could be recoated and another 375 prints made. Possibly this cycle can be repeated many times.

QUESTION: Is it necessary to use sodium carbonate solution for the removal of the lacquer or will any alkaline developer suffice?

\*MR. TALBOT: Laboratory tests indicate that any alkaline developer will remove the lacquer in about two minutes and that the neutral rinse following the developer is not absolutely necessary. The use of a carbonate-formalin bath followed by a neutral rinse gives an additional factor of safety, but it is believed that the coating can be completely removed by passing the treated film through a commercial processing machine.

QUESTION: Will the removal of the lacquer by developer harm the developer in any way?

\*MR. TALBOT: No, we believe not. The tests that we have run indicate that there is no change whatever in the action of the developer after its use to remove the lacquer. It would be necessary, however, to run this test on a much more extensive scale and with a wider variety of developers than we have used to be absolutely sure that no effect whatever occurs.

QUESTION: Is the lacquer available in large quantities?

\*MR. TALBOT: The lacquer which the Ace Laboratories have been using for the emulsion side only is available in large quantities. The universal lacquer which is applicable to both sides of nitrate and safety films is available at the moment in sample lots only (one gallon), but unless something entirely unforeseen happens, it will be available in large quantities in a few weeks.

### RECENT DEVELOPMENTS IN 8-MM COPPER-COATED HIGH-INTENSITY POSITIVE CARBONS\*

W. W. LOZIER, G. E. CRANCH, AND D. B. JOY\*\*

Since the introduction of the "Suprex" carbons about seven or eight years ago<sup>1</sup> there has been a remarkable expansion in the use of these small-diameter, copper-coated carbons. The rapid growth of this type of arc is evidenced by its use in the majority of all the medium-size theaters in the country. The wide acceptance of

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\* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received October 25, 1940.

\*\* National Carbon Company, Fostoria, Ohio.

this high-intensity arc using a copper-coated non-rotating positive carbon and reflector type lamp is largely due to the resultant brilliant snow-white light on the projection screen and to the economy of operation. Recently there have been introduced lamps and carbons which have extended the use of the high-intensity arc to the smallest theaters in the form of the "One-Kilowatt Arcs."

Development work has continued in our laboratories on these non-rotating high-intensity carbons. This paper reports the progress on a new 8-mm copper-coated carbon of this type which, however, is not yet ready for distribution. This new

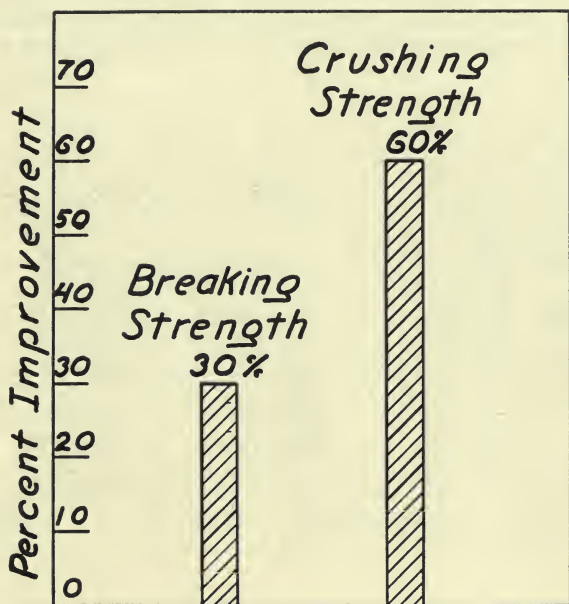


FIG. 1. Improvement in strength of carbon shells; experimental 8-mm shell over present 8-mm shell.

carbon is stronger, produces light more efficiently, burns more steadily, and can be operated at higher currents than the present 8-mm "Suprex" positive.

#### CHARACTERISTICS AND PERFORMANCE OF THE NEW CARBON

*Strength of the Carbon.*—Carbon shells under stress deform only a small amount before they fracture, and therefore do not give the warning of the proximity of fracture that would be conveyed by a more deformable material of the same ultimate strength. This should be kept in mind in clamping the carbons in the carbon holders, which in most "Suprex" type lamps exert a powerful leverage capable of cracking the carbons if excess pressure is used. This is particularly true in the case of the positive carbon holder. The result of this cracking, which



may be either transverse or longitudinal, is concealed by the copper coating but becomes evident when the carbon has been advanced in the holder and consumed to the point where the fracture exists. It is therefore of extreme importance that care be taken in clamping carbons in holders firmly but not excessively, and also in avoiding dropping carbons on the floor or otherwise mistreating them.

This new experimental carbon has a shell with both a higher transverse breaking strength and a higher crushing strength than the present one, as indicated in Fig. 1. Transverse breaking strength has been increased by 30 per cent, and the crushing strength, which is intimately connected with the action of the holder on the carbon, has been increased by 60 per cent. Therefore this increase in shell strength gives more assurance that these carbons will be free from breaks and cracks during the burning period. However, it does not mean that they are un-

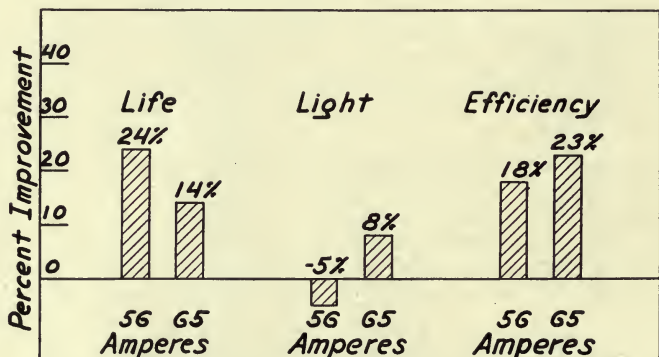


FIG. 2. Per cent improvement in operating characteristics of experimental 8-mm copper-coated high-intensity positive carbons over 8-mm "National" "Suprex."

breakable, but that they have a substantially increased factor of safety with respect to breakage.

*Burning Performance.*—This experimental carbon has 24 per cent longer life at 56 amperes, the lower limit of its current range, and 14 per cent longer life at 65 amperes, which is the maximum current for which the present 8-mm "Suprex" carbon is rated. Moreover this is accomplished with only a 5-per cent reduction in screen light at 56 amperes and an actual increase of 8 per cent in screen light at 65 amperes.

If the amount of screen light is multiplied by the burning life, a measure of the efficiency of utilization of the carbon is obtained. For example, the product of the screen light in lumens and the burning life in hours per inch gives the total light energy in lumen-hours per inch of positive carbon. Fig. 2 shows that this experimental carbon gives materially more light energy per inch of positive carbon consumed, ranging from an 18-per cent increase at 56 amperes to a 23-per cent increase at 65 amperes. At 59 amperes the consumption of the experimental carbon is the same as that of the present 8-mm "Suprex" at 56 amperes but the new

carbon under these conditions gives 10 per cent more light. Similarly, at 63 amperes the new carbon matches the consumption of the present "Suprex" at 60 amperes but gives 10 per cent more light. These figures show that the user will be getting substantially more light energy per carbon.

Arcs operated with the low-voltage power sources commonly used with "Suprex" type lamps often show noticeable current fluctuation. This, as has been shown in an earlier publication,<sup>2</sup> is the result of a compensating action between the arc and the power source such that the current responds to momentary voltage changes in a manner tending to maintain a steady light output. The experimental carbon, particularly at the higher currents, gives a more stable arc and thereby eliminates to a large extent the necessity of compensating current fluctuations. Fig. 3 shows the superior stability at 65 amperes of the new carbon compared to the present 8-mm "Suprex."

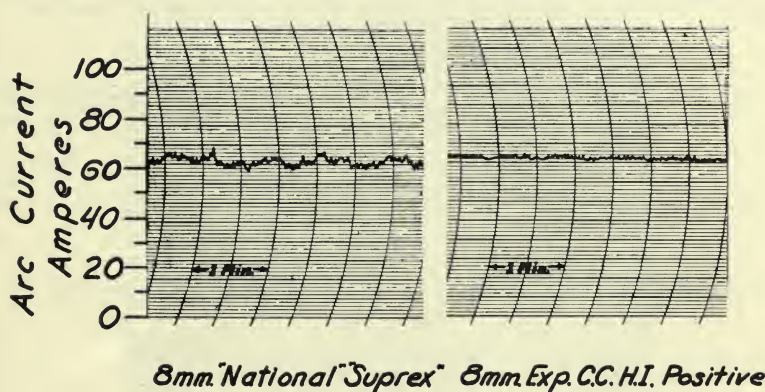


FIG. 3. Records of the arc current showing the improved stability of the experimental 8-mm carbon over the 8-mm "National" "Suprex" positive.

In some theaters now using "Suprex" carbons it would be desirable to obtain more light than can be obtained with the present 8-mm positive carbon at 65 amperes. Higher currents have not been feasible because it has been found that the present 8-mm "Suprex" positive can not be operated much above its maximum current rating of 65 amperes without excessive current fluctuation. The experimental 8-mm positive carbon does not show this undesirable feature even at 70 amperes and opens up the possibility of obtaining further increases in light.

At 68 amperes the new carbon has the same consumption rate as the present "Suprex" at 65 amperes but gives about 20 per cent more light. At 70 amperes the new carbon delivers about 25 per cent more light with about 10 per cent higher consumption rate than the present "Suprex" at 65 amperes. When the current is increased from 65 to 70 amperes at the same arc length, the arc voltage increases about 2 volts. This increase in arc current and voltage might exceed the capacity of some of the power sources while the increased consumption is too great for most of the feed motors. However, the increase in voltage can be avoided by shortening the arc length about 0.05 inch, which will also reduce the consumption at 70 am-

peres so that some of the lamps can feed the carbons rapidly enough. With these higher consumption rates, it is important that the negative be carried at its correct position because the crater face can become malformed very quickly if a poorly aligned negative is not corrected promptly.

When low-voltage power sources designed for "Suprex" type lamps and carbons are used, the new carbon can be burned from 56 to 70 amperes subject at 70 amperes to the limitations just described. In a few theaters there are still some old, high-voltage generators originally designed for *Hi-Lo* lamps. With these power sources, best results will be obtained with the new carbon if the current is maintained at or above 60 amperes.

This experimental 8-mm copper-coated high-intensity positive carbon has the best features of the present "Suprex" carbon and in addition has the advantages of greater strength, higher efficiency, steadier operation, and a wider current range, and therefore represents a significant advance over the present carbon.

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### A MOLDED PLASTIC SCREEN WITH CONTOURED SURFACE \*

ROBERT O. WALKER\*\*

The new screen, molded of plastic, represents a departure from the conventional. Its surface is not flat, but is smoothly contoured in a system of elliptical convexities forming a toric curve around each hole. Instead of being perforated in the usual manner, it is provided with holes molded in the shape of flaring horns, the sidewalls of the holes forming part of the surface contours. The screen has no seams, being molded as a single sheet in sizes up to 30 feet wide, with the plastic contoured to its three-dimensional pattern.

This pattern is shown in Fig. 1, which represents the screen photographed normal to the surface while illuminated by a flat light striking at a 10-degree inclination. When Fig. 1 is observed for more than a few seconds, the phenomenon of alternate direct and reverse pseudoscopic vision will cause the contours to appear convex at one moment, concave the next. They are actually convex. One set of waves undulates on a right diagonal, the other on a left diagonal. A chevron pattern is formed by the position of the various crossing points of the two sets of waves.

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\* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received October 20, 1940.

\*\* Walker-American Corp., St. Louis, Mo.



Fig. 2 shows the structure. These molded contours are elliptical in cross-section, sweeping in a curve from the base of one hole to the base of the next adjacent hole, and forming a modified toric curve around each hole.

Fig. 3 is a photomicrograph of a cross-section of the screen taken between two holes, showing the shape of the contour and sidewalls of the holes. The thickness is slightly under 0.025 inch, with the plastic surface bonded to a cloth backing approximately 0.010 inch thick. Forming the walls of each hole, the plastic extends in a thin ring through to the very back of the screen, thoroughly sealing the backing.

While the single sheet of plastic that forms the surface is thick enough to support its own weight, it requires reinforcement to prevent tearing under impact. Consequently, a strong cotton drill is impregnated with fire-retarding salts, a re-

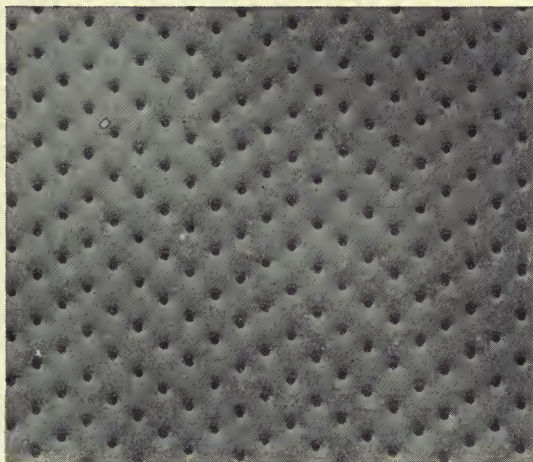


FIG. 1. Patterns of molded holes, photographed normal to the screen surface.

sin, and a bonding agent. Placed under the plastic surface and thoroughly sealed, the structure is moisture-proof. This backing comprises strips 51 inches wide running vertically, and welded together at their edges in such a manner as to leave the frontal face of the backing smooth and flush under the one-piece plastic surface.

The advantages of the plastic structure are many. Primarily, it is the only suitable medium in which these contours can be formed. Such a surface, molded as a single piece, possesses absolute uniformity from edge to edge of the entire screen. The customary seam, with its steadily increasing visibility, is eliminated. The durability of this hard, tough structure is obvious. There are no cut fibers to absorb dirt and moisture in and around the holes, thereby eliminating a great cause of deterioration.

The smooth, hard surface, contoured in easy curves, provides no lodging places for dust and dirt. Tests show that this structure collects dirt at less than half the

usual rate. Collection and impaction of dirt in the holes, so detrimental to sound transmission, are virtually eliminated by the widely flaring horn-shaped holes, permitting maintenance of sound transmission at proper levels.

The plastic employed is moderately flexible, hard, and tough at normal temperatures. It softens at temperatures above  $140^{\circ}\text{F}$ . When cold, at temperatures below  $50^{\circ}\text{F}$ , it becomes progressively brittle. It must not be unrolled or bent when cold, but once stretched, cold will not affect it adversely. This is the familiar characteristic of all thermoplastic materials—loss of flexibility when cold. The screen is rolled for shipment in the usual manner, and is stretched by lacing within a frame in the customary fashion. Installation is no more difficult. While the plastic screen weighs three times as much as conventional types, and requires more care due to that weight, it is very easy to stretch flat, as it is molded without

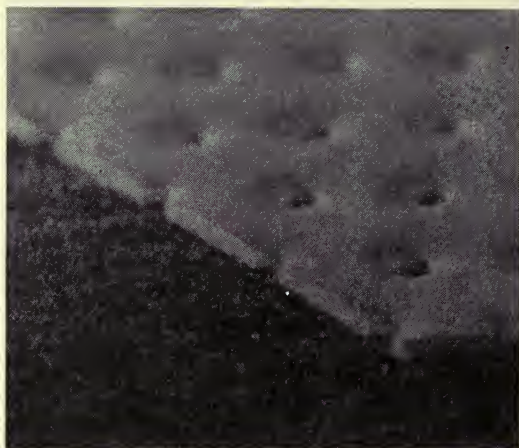


FIG. 2. Showing the structure of the screen.  
The shadows show the contour of the surface.

wrinkles. Resistance to penetration is high. Damage from small missiles will be sharply reduced. Most small dents disappear in a few days. The screen is, of course, fire resistant.

The open area at the bottom of the holes, through which light is lost, amounts to 8.1 per cent of the total area. Overall reflective efficiency is 86 per cent, including the loss through the holes. The contour of the surface causes no sacrifice of light, as there is no baffle effect. It does improve distribution within the usable area. No disturbance of focus is caused, as the most critical projection lens has a depth of focus several hundred times the depth of this surface.

The high reflective efficiency of the surface does not account for the visual effect produced. More of the light normally wasted in extreme side reflection is directed diffusely within the 120 degrees of the usable area. The plastic employed is transparent and nearly colorless, with a low refractive index. It is loaded by a new technic with a combination amorphous and crystalline pigment mixture pos-

sessing a very high refractive index. The overall result is the properly balanced high spectral response necessary for correct color reproduction, with a wide latitude of tone and color.

The shape of the holes, as shown by Fig. 3, is obviously beneficial to sound transmission. The air-column load and viscosity effect common to the normal perforation is sharply reduced by the widely flaring sides of the molded hole. The rough ends of severed fibers and broken coating are replaced by a smooth plastic wall. The flaring horn shape of the hole permits improved angular distribution of sound.

In theory, the elliptical contours of this surface should produce a different kind of picture. In practice, this has been the result. As one of these screens forms part of the projection installation at this meeting, opportunity has been provided for observing what it delivers. The contoured imaging surface appears definitely to have influenced the illusion of depth. The "window effect" is increased. Technicolor shows the illusion at its best. Observers of a number of installations have commented upon a lack of flatness, apparent separation of fore and background to a greater degree, reduction in one's consciousness of the screen, and the effect of an image being formed in the air. While this surface plainly does not produce stereoscopic vision, a third dimension, or anything startling, it does produce an effect of depth that can not be evaluated but can be observed.



FIG. 3. Photomicrograph of section of screen showing elliptical contour in profile.

It is interesting to note the effect of this surface upon perspective, or the ability of the eye to estimate its position in space. If an observer will stand about two feet from a full-sized screen, far enough toward the center so that the masking is outside the line of vision, while the screen is illuminated by projected light or strong diffuse light, he will find difficulty in placing his finger within four inches of the correct plane of the screen after looking directly at it for thirty seconds. The finger will tend to select a point in space as the plane of the screen.

Why should these tiny elliptical and toric contours influence a perspective illusion? Our theory has been based upon the psychology of monocular vision. Close one eye and one can still perceive solidity and perspective in the image formed on the retina. Helmholtz established the principle that recognition plays a part in the image perceived. The eye is accustomed to perspective, and it will build a mental image of perspective to aid the real image, if given the slightest assistance. This surface appears to provide something which aids that mental image.

In this structure, 60 per cent of the picture falls upon the elliptically contoured area, and 40 per cent upon the toric curves surrounding each of the holes, thereby breaking the picture into a number of minute portions. These portions have varying angles in different image planes throughout the depth of the contours.



As the entire structure is uniform, these portions upon reflection must be resolved into a series of total images lying in a multiplicity of planes. Certain portions of the contours cause a difference in the angular width of the image portions as projected and as observed, due to the increase in the total surface area produced by the toric curves. The eye appears continuously to select certain minute characteristics found in normal perspective, integrate them with the image, and construct an added illusion of depth.

This effect is an illusion of the picture as a whole, and it can be destroyed by distractions. Of course, it can not be observed upon a portion or sample. It can be found on a full screen only. Too much should not be expected, as it is only another contribution to beautiful projection, moving the goal of realism a step closer.

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#### NOTE

The camera referred to in the paper entitled "The Twentieth Century Camera and Accessories" by D. B. Clark and G. Laube, published in the January issue of the JOURNAL on p. 50 is now known as the "Cine-Simplex" camera and is being manufactured for general distribution by the Cine-Simplex Corp., Syracuse, N. Y.

## CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

*The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliefilm Service, Department of Agriculture, Washington, D. C.*

### American Cinematographer

22 (January, 1941), No. 1

Making Modern Night-Effects (pp. 11, 38-39)

16-Mm Goes Professional (pp. 12, 34)

South American Makes Movies (pp. 13-14, 39-40)

Propose Standard Method of Determining Speed of Films (pp. 17, 40)

Making Micro-Movies in 16-Mm Kodachrome (pp. 24, 42-43)

W. W. KELLEY

W. STULL

C. F. NELSON

M. E. RUSSELL

P. R. NELSON

### British Kinematograph Society, Journal

3 (October, 1940), No. 4

The 16-Mm Film as an Aid to Science (pp. 159-166)

Recording 16-Mm Sound-Film from Double-Width Push-Pull Track (pp. 166-170)

The Intimate Use of 16-Mm Films (pp. 170-175)

Desirable Characteristics of Sub-Standard Projectors.

(I) Heavy-Duty Models (pp. 176-179)

J. YULE BOGUE

N. LEEVERS

H. E. DANCE

### Communications

20 (December, 1940), No. 12

Extended Experimental Study of the Optical Pattern (pp. 22, 24)

C. J. LEBEL

### Educational Screen

19 (December, 1940), No. 10

Motion Pictures—Not for Theaters, Pt. 22 (pp. 417-419)

A. E. KROWS

### International Projectionist

15 (November, 1940), No. 11

Sound Heads on Parade: 1927-1940 (pp. 7-8, 11-12)

The New "Orotip. C" Negative Carbon for Low-Amperage Lamps (pp. 15-18)

P. P. MELROY

W. W. LOZIER,

D. B. JOY, AND

R. W. SIMON

RCA's Fantasound System as Used for Disney's  
*Fantasia* (pp. 20-21, 24)

R. J. KOWALSKI

New Walker Plastic Molded Screen Is Highly Efficient  
(pp. 26, 37-38)

J. J. FINN

**Kinematograph Weekly**

286 (December 5, 1940), No. 1755

Projection with Sub-Standard Apparatus (pp. 9-10)

R. H. CRICKS

**Electronics**

13 (December, 1940), No. 12

An Electrically Focused Multiplier Phototube (pp.  
20-23, 58, 60)

J. A. FAJCHMAN AND  
R. L. SNYDER

**International Photographer**

12 (January, 1941), No. 12

Coöperative Research Laboratory Needed (pp. 8-9)

**Motion Picture Herald (Better Theaters Section)**

141 (December 14, 1940), No. 11

Preparation for a New Advance in Motion Picture  
Sound (pp. 30, 32-33)

**Photographische Industrie**

38 (November 6, 1940), No. 45

Über die Brauchbarkeit von Neophan-Filtern bei  
Farbenfilmaufnahmen (The Use of Neophan Filters  
in Color Photography) (pp. 664-666)

R. WEIZSAECKER



## 1941 SPRING CONVENTION

### SOCIETY OF MOTION PICTURE ENGINEERS

THE SAGAMORE HOTEL  
ROCHESTER, NEW YORK  
MAY 5th-8th, INCLUSIVE

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Officers and Members Rochester Projectionists Local No. 253

## HEADQUARTERS

The headquarters of the Convention will be the Sagamore Hotel, where excellent accommodations and moderate rates are assured. A reception parlor will be provided as headquarters for the Ladies' Committee.

Hotel reservation cards will be mailed to the members of the Society early in April. They should be filled out and mailed immediately to the Sagamore Hotel so that suitable accommodations may be reserved, subject to cancellation if unable to attend the convention.

The following European-plan day rates are extended by the Sagamore Hotel to Society members and guests attending the Convention (all rooms are outside rooms with bath):

Room for one person	\$3.00 to \$5.00
Room for two persons, double bed	4.50 to 6.00
Room for two persons, twin beds	6.00 to 7.00
Suite accommodations, one to four persons	12.00 and up

The following hotel garage rates will be available to SMPE delegates and guests who motor to the Convention: 24-hr. inside parking, 75¢; outside parking (daily), 25¢.

The colorful *Sagamore Room* on the main floor of the Hotel offers special breakfast, luncheon, and dinner menus at moderate prices.

Golfing privileges at several Rochester country clubs may be arranged for either by the hotel management or at the SMPE registration headquarters.

## REGISTRATION

Convention registration and information headquarters will be located on the Sagamore Hotel roof, adjacent to the *Glass House*, where all technical sessions and symposiums will be held.

Members and guests attending the Convention will be expected to register, and so help to defray the Convention expenses. Convention badges and identification cards will be provided for admittance to all regular and special sessions during the Convention. The identification card will also be honored through the courtesy of Loew's Theaters, Inc., at Loew's *Rochester Theater* and, through the courtesy of Monroe Amusements, Inc., at the *Palace, Regent, and Century Theaters*,

Group visits to various plants in Rochester and vicinity may be arranged at the Registration Desk.

#### TECHNICAL SESSIONS

All the technical sessions of the Convention will be held in the *Glass House* on the roof of the Sagamore Hotel with the exception of Wednesday evening, as described below. Members should note that the banquet, which at past conventions has always been held on Wednesday evening, this time has been scheduled for Tuesday evening to permit holding a special meeting on Wednesday evening at the *Eastman Theater*.

Wednesday, May 7th, will be devoted to a joint meeting of the Acoustical Society of America and the SMPE, consisting of a symposium of papers by engineers of the Bell Telephone Laboratories in the morning and afternoon. In the evening a demonstration of stereophonic sound will be given by the Bell Telephone Laboratories at the *Eastman Theater*.

#### LUNCHEON AND BANQUET

The usual Informal Get-Together Luncheon for members, their families, and guests will be held in the *Starlight Room* on the hotel roof on Monday, May 5th, at 12:30 P. M.: short addresses by prominent speakers; names to be announced later. Luncheon and banquet tickets should be procured when registering.

The 48th Semi-Annual Banquet and Dance will be held in the *Starlight Room* on the hotel roof on Tuesday evening, May 6th, at 7:30 P. M.: music and entertainment. Banquet tickets should be procured and tables reserved at registration headquarters by noon of Tuesday, May 6th.

#### LADIES' PROGRAM

Mrs. C. M. Tuttle, *Convention Hostess*, and members of her Committee are arranging a very attractive program of entertainment for the ladies attending the Convention. A reception parlor will be provided for the use of the Committee during the Convention.

#### PROGRAM

##### *Monday, May 5th*

9:00 a. m.	<i>Sagamore Hotel Roof</i> Registration
9:30 a. m.-12:00	<i>Glass House, Hotel Roof</i> Technical session
12:30 p. m.	<i>Starlight Room, Hotel Roof</i> Get-Together Luncheon for members, their families, and guests. Brief addresses by several prominent speakers
2:00 p. m.	<i>Glass House, Hotel Roof</i> Technical session
8:00 p. m.	<i>Glass House, Hotel Roof</i> Technical session



**Tuesday, May 6th**

- 9:00 a. m. *Sagamore Hotel Roof*  
Registration
- 9:30 a. m. *Glass House, Hotel Roof*  
Society Business  
Technical session
- 12:30 p. m. Luncheon period  
Program for this afternoon to be announced later
- 7:30 p. m. *Starlight Room, Hotel Roof*  
Semi-Annual Banquet and Dance of the SMPE: addresses  
and entertainment: music, dancing, and entertainment

**Wednesday, May 7th**

- 10:00 a. m. *Glass House, Hotel Roof*  
Technical session
- 12:30 p. m. Luncheon period
- 2:00 p. m. *Glass House, Hotel Roof*  
Stereophonic sound papers session
- 8:00 p. m. *Eastman Theater*  
Stereophonic sound demonstration for the SMPE Convention and invited groups. Admission only by SMPE identification card, or special invitation card

**Thursday, May 8th**

- 10:00 a. m. *Glass House, Hotel Roof*  
Technical session
- 12:30 p. m. Luncheon period
- 2:00 p. m. *Glass House, Hotel Roof*  
Technical and business session

**ADJOURNMENT**

W. C. KUNZMANN,  
*Convention Vice-President*

## SOCIETY ANNOUNCEMENTS

### ATLANTIC COAST SECTION

At a meeting of the Section held at the Hotel Pennsylvania, New York, N. Y., on January 15th, Mr. Lawrence R. Martin, Production Technician, Camera Works, Eastman Kodak Company, Rochester, N. Y., presented a paper on "The Motion Picture as a Tool in Science and Engineering."

Mr. Martin discussed applications of the motion picture apart from the usual role the motion picture plays in the theater as a vehicle of entertainment. Methods were described of recording the indications of aeroplane panel instruments, reactions of the aeroplane operator while flying, irregularities of motion in production machinery, calibration of special gasoline storage tanks, and study of the action of locomotive wheels upon the rails. Sixteen-mm pictures showing these various applications were projected.

The next meeting of the Section will be held on February 19th.

### SECTIONAL COMMITTEE ON MOTION PICTURES (Z-22)

As the result of balloting by the Standards Council of the American Standards Association, the Standards and Recommended Practices listed below have been approved by the A. S. A. as of January 10, 1941. It is expected that these Standards and Recommended Practices will be published in the March issue of the JOURNAL:

#### *American Standards*

35-mm Sound Film; Emulsion and Sound Record Positions in Camera—Negative.

35-mm Sound Film; Emulsion and Sound Record Positions in Projector—Positive (for Direct Front Projection).

35-mm Film; Projection Reels.

16-mm Silent Film; Cutting and Perforating Negative and Positive Raw Stock.

16-mm Film; Projector Sprockets.

16-mm Silent Film; Camera Aperture.

16-mm Silent Film; Projector Aperture.

16-mm Silent Film; Emulsion Position in Camera—Negative.

16-mm Silent Film; Emulsion Position in Projector—Positive (for Direct Front Projection).

16-mm Film; Projection Reels.

16-mm Silent Film; Cutting and Perforating Negative and Positive Raw Stock.

16-mm Sound Film; Camera Aperture.

16-mm Sound Film; Projector Aperture.

16-mm Sound Film; Emulsion and Sound Record Positions in Camera—Negative.

16-mm Sound Film; Emulsion and Sound Record Positions in Projector—Positive.

8-mm Film, Cutting and Perforating Negative and Positive Raw Stock.

8-mm Film; 8-Tooth Projector Sprockets.

8-mm Silent Film; Camera Aperture.

8-mm Silent Film; Projector Aperture.

8-mm Silent Film; Emulsion Position in Camera—Negative.

8-mm Silent Film; Emulsion Position in Projector—Positive (for Direct Front Projection).

8-mm Silent Film; Projection Reels.

*American Recommended Practices*

16-mm Silent Film; Film Splices—Negative and Positive.

16-mm Sound Film; Film Splices—Negative and Positive.

Sensitometry.

Photographic Density.

Projection Rooms.

Projection Screens.

Nomenclature.

Safety Film.

Fader Setting Instructions.

Nomenclature for Filters.

**INTER-SOCIETY COLOR COUNCIL**

The Tenth Annual Meeting of the Council will be held March 3 to 5, 1941, at Washington, D. C. The technical session will be co-sponsored by the American Society for Testing Materials, and will be held on March 5th during their eastern regional meetings. Delegates and members of the Council are urged to be present, and members of all member-bodies and any others interested in color are invited to attend the sessions. Information concerning the detailed program may be obtained by request from the Secretary of the I. S. C. C. (Box 155, Benjamin Franklin Station, Washington, D. C.) after February 1st.



# MOTION PICTURE ENGINEERS

## March, 1941

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# JOURNAL

## OF THE SOCIETY OF

# MOTION PICTURE ENGINEERS

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\*Term expires December 31, 1941.

\*\*Term expires December 31, 1942.

# AMERICAN MOTION PICTURE STANDARDS AND RECOMMENDED PRACTICES

## FOREWORD

The following American Standards and Recommended Practices (Z22.2 to Z22.35) comprise the entire body of motion picture projects approved by the American Standards Association, and in force at the present date. Z22.34 and Z22.35 were approved September 20, 1930; all the others listed below were approved January 10, 1941, either as revisions of previous specifications or as entirely new standards or recommended practices. In some instances the revisions consist only in changes of Z-numbers. The present publication supersedes all previous publications of American Motion Picture Standards and Recommended Practices.

## AMERICAN STANDARDS

- Z22.2 35-Mm Sound Film; Emulsion and Sound Record Position in Camera—  
Negative
- Z22.3 35-Mm Sound Film; Emulsion and Sound Record Positions in Pro-  
jector—Positive. For Direct Front Projection.
- Z22.4 35-Mm Film; Projection Reels
- Z22.5 16-Mm Silent Film; Cutting and Perforating Negative and Positive  
Raw Stock
- Z22.6 16-Mm Film; Projector Sprockets
- Z22.7 16-Mm Silent Film; Camera Aperture
- Z22.8 16-Mm Silent Film; Projector Aperture
- Z22.9 16-Mm Silent Film; Emulsion Position in Camera—Negative
- Z22.10 16-Mm Silent Film; Emulsion Position in Projector—Positive. For  
Direct Front Projection
- Z22.11 16-Mm Film; Projection Reels
- Z22.12 16-Mm Sound Film; Cutting and Perforating Negative and Positive  
Raw Stock
- Z22.13 16-Mm Sound Film; Camera Aperture
- Z22.14 16-Mm Sound Film; Projector Aperture
- Z22.15 16-Mm Sound Film; Emulsion and Sound Record Positions in Camera—  
Negative
- Z22.16 16-Mm Sound Film; Emulsion and Sound Record Positions in Pro-  
jector—Positive
- Z22.17 8-Mm Film; Cutting and Perforating Negative and Positive Raw  
Stock



- Z22.18 8-Mm Film; 8-Tooth Projector Sprockets
- Z22.19 8-Mm Silent Film; Camera Aperture
- Z22.20 8-Mm Silent Film; Projector Aperture
- Z22.21 8-Mm Silent Film; Emulsion Position in Camera—Negative
- Z22.22 8-Mm Silent Film; Emulsion Position in Projector—Positive. For  
Direct Front Projection
- Z22.23 8-Mm Silent Film; Projection Reels
- Z22.34 35-Mm Film; Cutting and Perforating Negative and Positive Raw  
Stock
- Z22.35 35-Mm Film; 16-Tooth Projector Sprockets

#### AMERICAN RECOMMENDED PRACTICES

- Z22.24 16-Mm Silent Film; Film Splices—Negative and Positive
- Z22.25 16-Mm Sound Film; Film Splices—Negative and Positive
- Z22.26 Sensitometry
- Z22.27 Photographic Density
- Z22.28 Projection Rooms
- Z22.29 Projection Screens
- Z22.30 Nomenclature
- Z22.31 Safety Film
- Z22.32 Fader Setting Instructions
- Z22.33 Nomenclature for Filters

#### INFORMATIONAL DATA

##### Unit of Photographic Intensity

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The formulation of these Standards and Recommended Practices is the result of effective collaboration over a long period by a large number of important groups in the motion picture industry. The continued and valuable coöperation of the Research Council of the Academy of Motion Picture Arts and Sciences, and of the Society of Motion Picture Engineers are gratefully acknowledged. The work of preparation and the method of approval were in accordance with the Sectional Committee procedure of the American Standards Association. It will be noted that no references are given in the standards or recommended practices to the originating sources of such material. Where specific publications are mentioned as a matter of information, the references are given in footnotes where the complete publications in question could not conveniently be included in the text.

The membership of the Sectional Committee on Motion Pictures (Z22) is as follows:

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Agfa Ansco Corporation

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gresses of Photography

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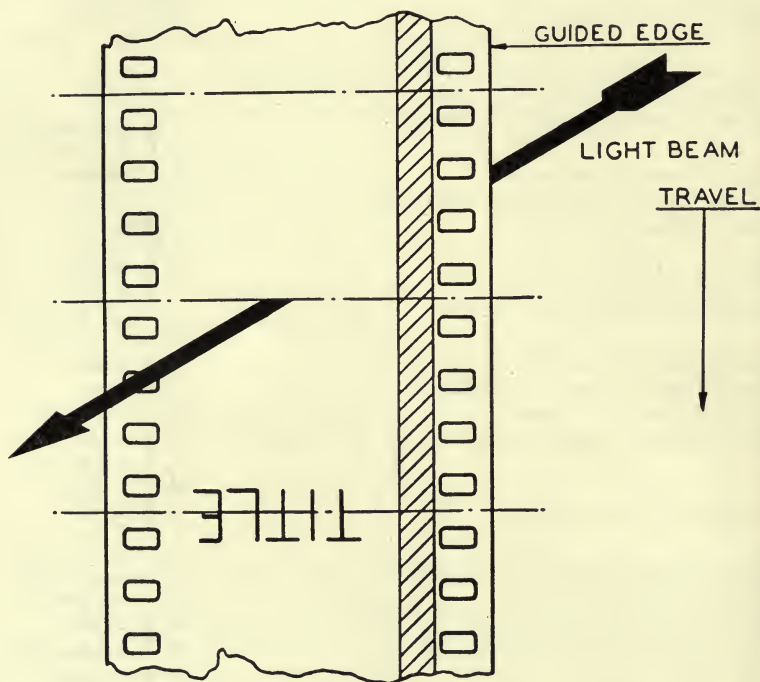
SYLVAN HARRIS, *Secretary*

January 12, 1941

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\* Alternate.

AMERICAN STANDARD For 35 mm Sound Film	ASA Z22.2 1941
EMULSION AND SOUND RECORD POSITIONS IN CAMERA—NEGATIVE	



*Drawing shows film as seen from inside the camera looking toward the camera lens.*

- (1) Emulsion position in camera: *toward the lens, except for special processes.*
- (2) Speed: 24 frames per second.
- (3) Distance between center of picture and corresponding sound: 20 frames.

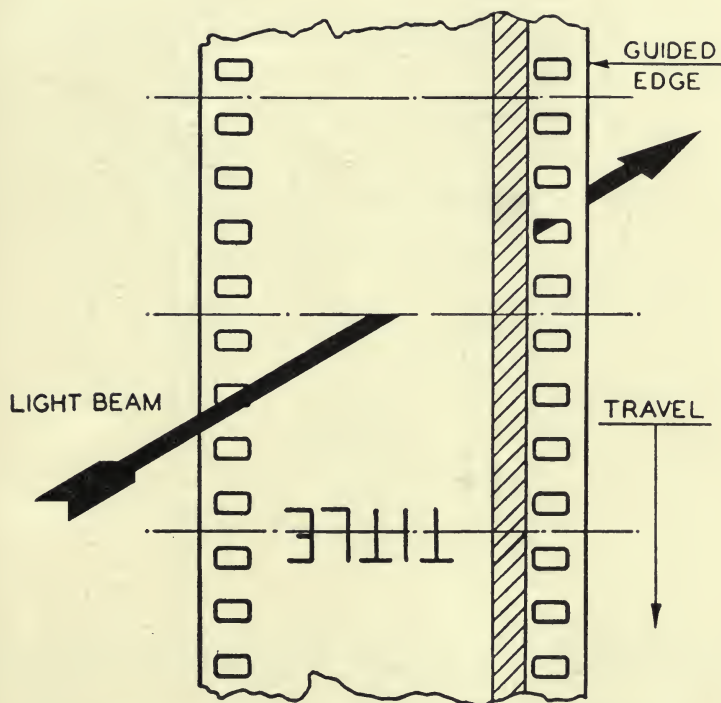


**AMERICAN STANDARD  
For 35 mm Sound Film****EMULSION AND SOUND RECORD  
POSITIONS IN PROJECTOR—POSITIVE  
For Direct Front Projection**

ASA

Z22.3

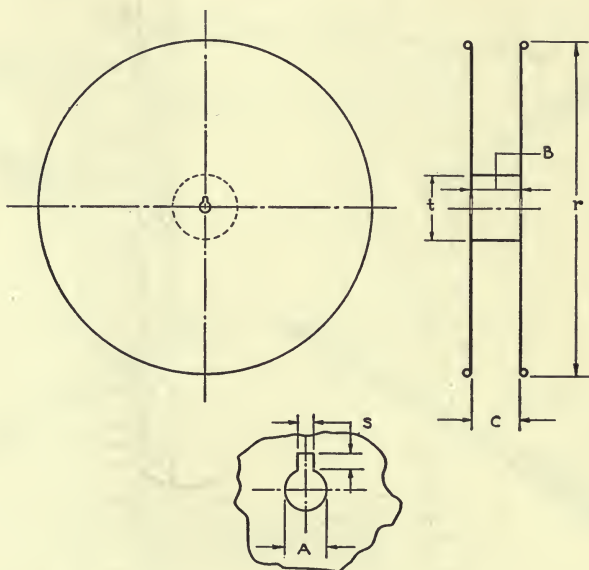
1941



*Drawing shows film as seen from the light-source in the projector.*

- (1) Emulsion position in projector: *toward the light-source, except for special processes.*
- (2) Speed: 24 frames per second.
- (3) Distance between center of picture and corresponding sound: 20 frames.

AMERICAN STANDARDS For 35 mm Film	ASA Z22.4 1941
PROJECTION REELS	



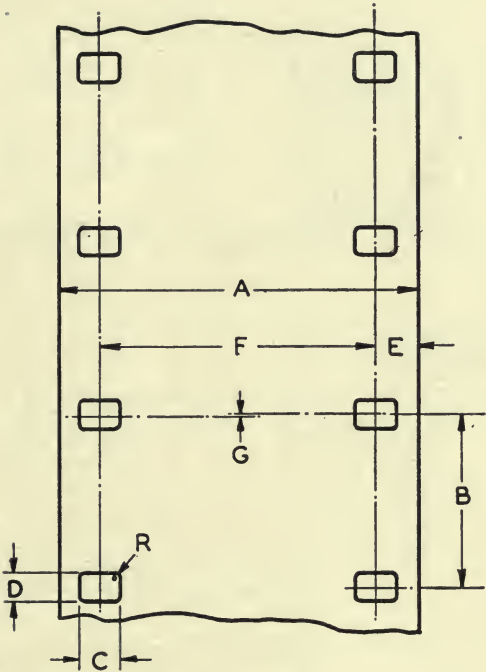
Capacity	300 Meters	1000 Feet	600 Meters	2000 Feet
	Millimeters	Inch Equivalents	Millimeters	Inch Equivalents
A	8.3 Min.	0.328 Min.	8.3 Min.	0.328 Min.
B*	40.1	1.58	40.1	1.58
C	38.1	1.50	38.1	1.50
<i>Recommended Practice</i>				
r	254.0	10.0	368.0	14.5
s	3.17	0.125	3.17	0.125
t	50.8	2.0	101.6	4.0

\* This dimension applies only within a radius of 0.5 inch from the axis of the reel.

AMERICAN STANDARD  
For 16 mm Silent Film

CUTTING AND PERFORATING  
NEGATIVE AND POSITIVE RAW STOCK

ASA  
Z22.5  
1941



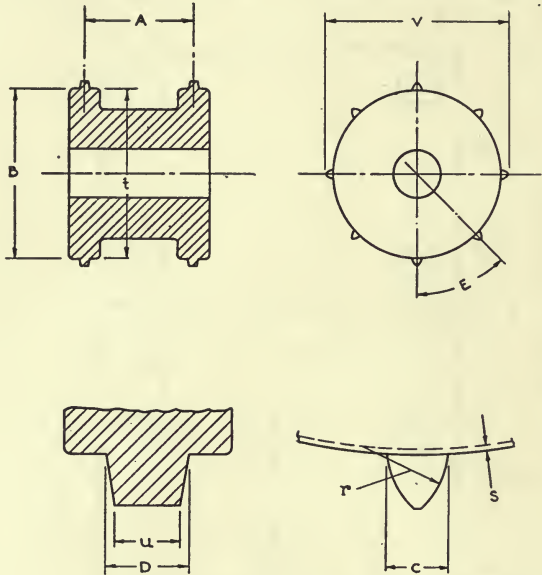
	Millimeters	Inch Equivalents
A	16.00 + 0.00 - 0.05	0.630 + 0.000 - 0.002
B	7.620 ± 0.013	0.3000 ± 0.0005
C	1.83 ± 0.01	0.0720 ± 0.0004
D	1.27 ± 0.01	0.0500 ± 0.0004
E	1.83 ± 0.05	0.072 ± 0.002
F	12.320 ± 0.025	0.485 ± 0.001
G	Not > 0.025	Not > 0.001
L*	762.00 ± 0.76	30.0 ± 0.03
R	0.25	0.010

\* L = the length of any 100 consecutive perforation intervals.

These dimensions and tolerances apply to the material immediately after cutting and perforating.



AMERICAN STANDARD For 16 mm Film		ASA Z22.6 1941
PROJECTOR SPROCKETS		



Number of Teeth in Mesh											
		3		4		5		6			
Combina- tion	N	B		C		C		C		C	
		Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
Feed	6	14.38	0.566	60°0'	± 0.5'	1.02	0.040				
	8	19.23	0.757	45°0'	± 0.5'	1.02	0.040	0.91	0.036		
	12	28.93	1.139	30°0'	± 0.5'	1.02	0.040	0.91	0.036	0.79	0.031
	16	38.63	1.521	22°30'	± 0.5'	1.02	0.040	0.91	0.036	0.79	0.031
Take-Up (Holdback)	6	14.15	0.557	60°0'	± 0.5'	1.02	0.040				
	8	18.92	0.745	45°0'	± 0.5'	1.02	0.040	0.91	0.036		
	12	28.50	1.122	30°0'	± 0.5'	1.02	0.040	0.91	0.036	0.79	0.031
	16	38.05	1.498	22°30'	± 0.5'	1.02	0.040	0.91	0.036	0.79	0.031
	6	14.30	0.563	60°0'	± 0.5'	1.09	0.043				
	8	19.13	0.753	45°0'	± 0.5'	1.09	0.043	1.02	0.040		
	12	28.78	1.133	30°0'	± 0.5'	1.09	0.043	1.02	0.040	0.94	0.037
	16	38.43	1.513	22°30'	± 0.5'	1.09	0.043	1.02	0.040	0.94	0.037

For All Sprockets	Millimeters		Inch Equivalents	
	A	D	r	s
	12.22 + 0.05	0.481 + 0.002	0.050	0.003
	- 0.00	- 0.000		
	1.22 + 0.00	0.048 + 0.000		
	- 0.08	- 0.003		
	1.27	0.050		
	0.08	0.003		
	B - 0.3, Max.	B - 0.01, Max.		
	1.00	0.039		
	B + 1.52, Max.	B + 0.060, Max.		

Notes

N = Number of teeth on sprocket.

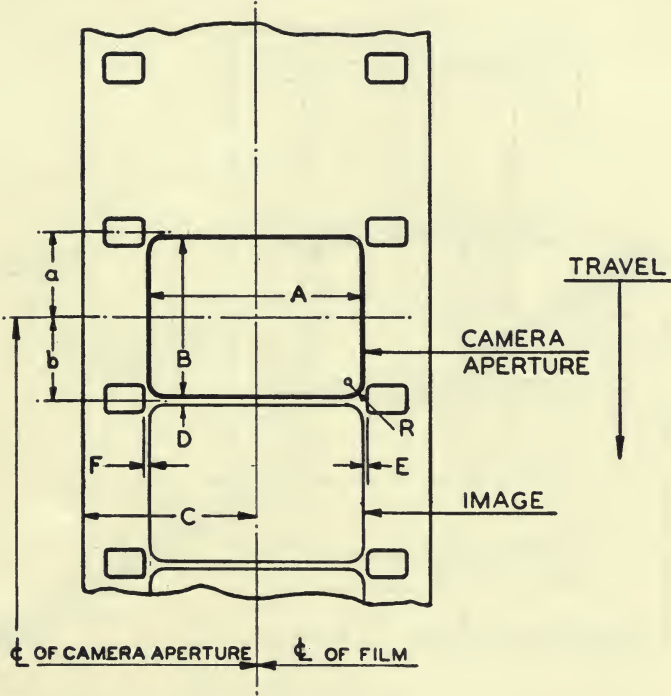
Tolerance for B and C +0.000 to -0.025 mm. or +0.000 to -0.001 in.

Dimensional standards indicated by capital letters.

Recommended practice indicated by lower case letters.

Values of C are omitted in cases where the angle of wrap on the sprocket would exceed 180°.

AMERICAN STANDARD For 16 mm Silent Film	ASA Z22.7
CAMERA APERTURE	1941

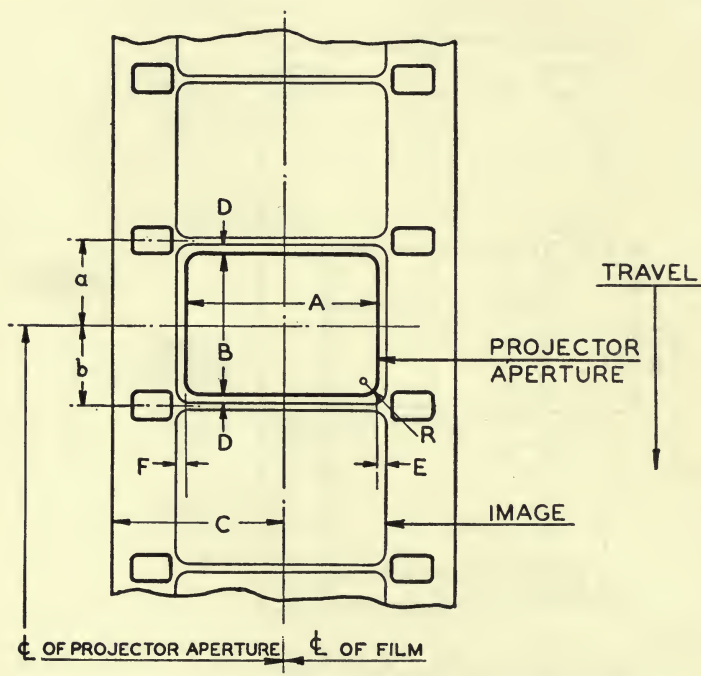


	Millimeters	Inch Equivalents
A	10.41 ± 0.05	0.410 ± 0.002
B	7.47 ± 0.05	0.294 ± 0.002
C	8.00 ± 0.05	0.315 ± 0.002
D	0.15	0.006
E	0.05	0.002
F	0.05	0.002
R	0.5 approx.	0.02 approx.
$a = b = \frac{1}{2}$ longitudinal perforation pitch.		

These dimensions and locations are shown relative to unshrunk raw stock.

The center of the frame-line shall pass through the centers of perforations on opposite sides of the film.

AMERICAN STANDARD For 16 mm Silent Film	ASA Z22.8
PROJECTOR APERTURE	1941



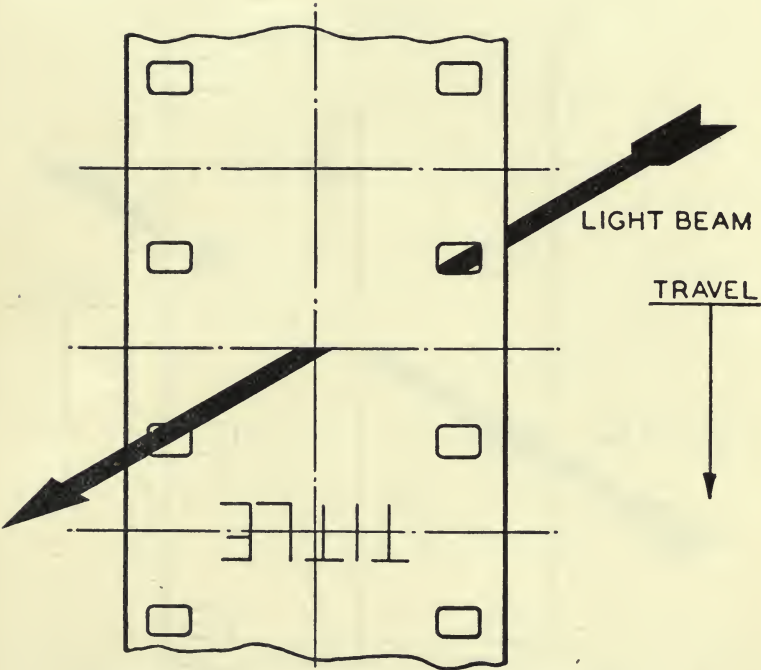
	Millimeters	Inch Equivalents
A	9.65 ± 0.05	0.380 ± 0.002
B	7.21 ± 0.05	0.284 ± 0.002
C	8.00 ± 0.05	0.315 ± 0.002
D	0.13	0.005
E	0.38	0.015
F	0.38	0.015
R	0.5 approx.	0.02 approx.
$a = b = \frac{1}{2}$ longitudinal perforation pitch.		

These dimensions and locations are shown relative to unshrunk raw stock.

The center of the frame-line shall pass through the centers of perforations on opposite sides of the film.



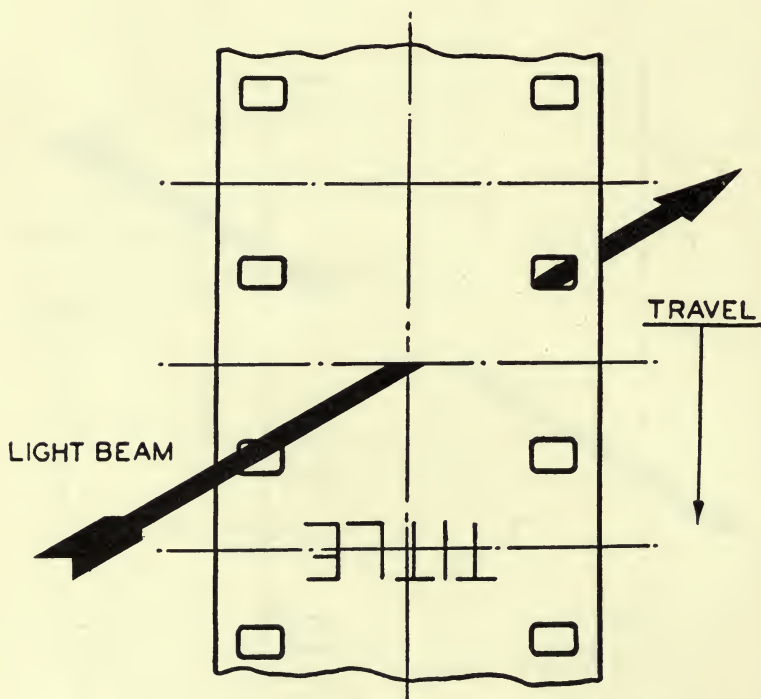
AMERICAN STANDARD For 16 mm Silent Film	ASA Z22.9
EMULSION POSITION IN CAMERA—NEGATIVE	1941



*Drawing shows film as seen from inside the camera looking toward the camera lens.*

- (1) Emulsion position in camera: *toward the lens, except for special processes.*
- (2) Normal speed: 16 frames per second.

AMERICAN STANDARD For 16 mm Silent Film	ASA Z22.10 1941
EMULSION POSITION IN PROJECTOR— POSITIVE For Direct Front Projection	



*Drawing shows film as seen from the light-source in the projector.*

- (1) Emulsion position in projector: *toward the lens, except for special processes.*
- (2) Normal speed: 16 frames per second.

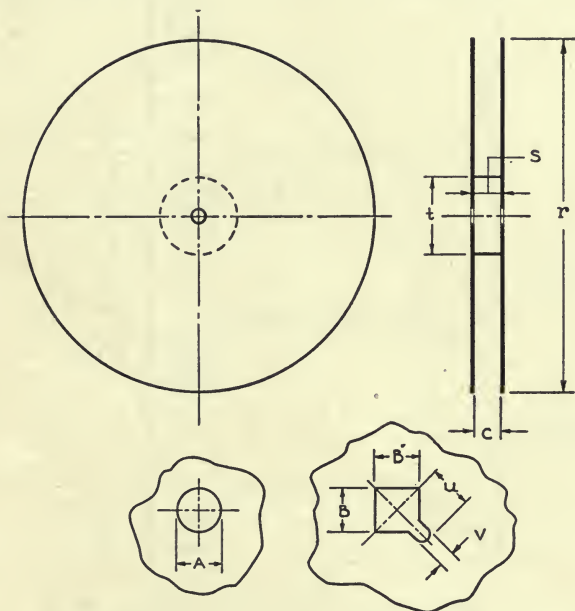
AMERICAN STANDARD  
For 16 mm Film

ASA

Z22.11

## PROJECTION REELS

1941

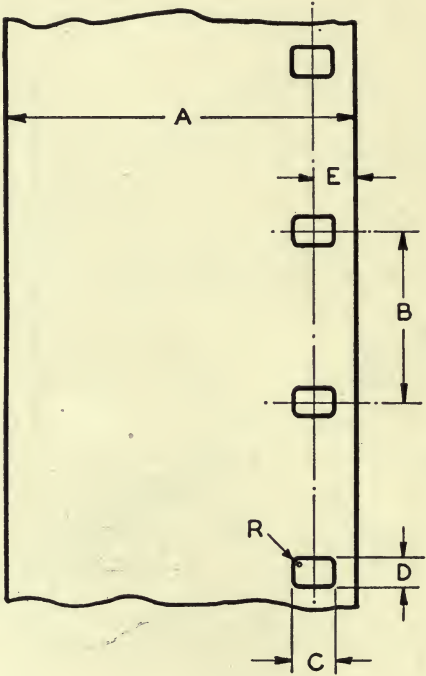


	120 Meters	400 Feet	240 Meters	800 Feet	480 Feet	1600 Feet
	Millimeters	Inch Equivalents	Millimeters	Inch Equivalents	Millimeters	Inch Equivalents
A	8.10 + 0.00 - 0.08	0.319 + 0.000 - 0.003	8.10 + 0.00 - 0.08	0.319 + 0.000 - 0.003	8.10 + 0.00 - 0.08	0.319 + 0.000 - 0.003
B	8.10 + 0.00 - 0.08	0.319 + 0.000 - 0.003	8.10 + 0.00 - 0.08	0.319 + 0.000 - 0.003	8.10 + 0.00 - 0.08	0.319 + 0.000 - 0.003
C	17.2 Min.	0.677 Min.	17.2 Min.	0.677 Min.	17.2 Min.	0.677 Min.
<i>Recommended Practice</i>						
r	177.8	7.00	250.8	9.87	355.6	14.00
s	19.23	0.757	19.63	0.773	21.92	0.863
t	37.85	1.490	37.85	1.490	117.48	4.625
u	7.94	0.312	7.94	0.312	7.94	0.312
v	3.17	0.125	3.17	0.125	3.17	0.125

NOTE: Center Spindle Holes—Either a combination of square and round holes or two square holes may be used.



AMERICAN STANDARD For 16 mm Sound Film	ASA Z22.12 1941
CUTTING AND PERFORATING NEGATIVE AND POSITIVE RAW STOCK	

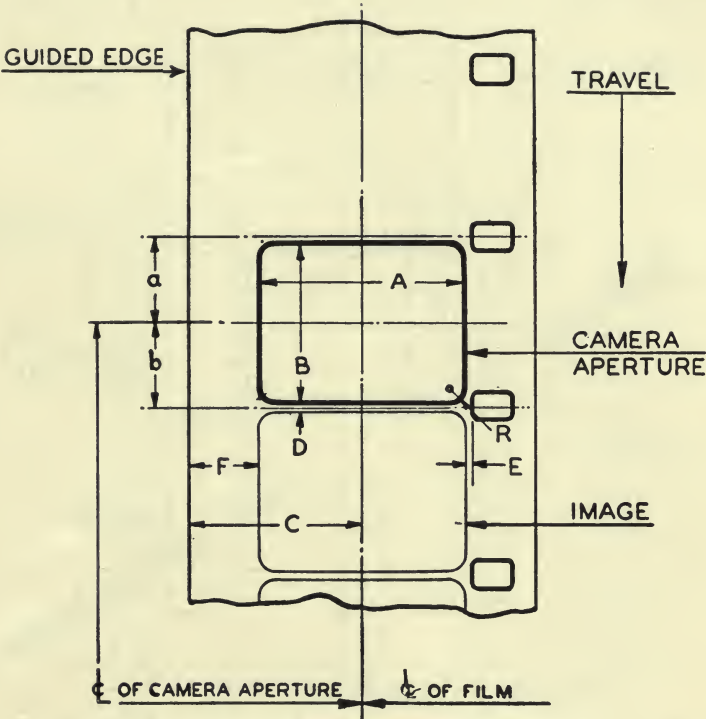


	Millimeters	Inch Equivalents
A	16.00 + 0.00 - 0.05	0.630 + 0.000 - 0.002
B	7.620 ± 0.013	0.3000 ± 0.0005
C	1.83 ± 0.01	0.0720 ± 0.0004
D	1.27 ± 0.01	0.0500 ± 0.0004
E	1.83 ± 0.05	0.072 ± 0.002
L*	762.00 ± 0.76	30.00 ± 0.03
R	0.25	0.010

\*L = the length of any 100 consecutive perforation intervals.

These dimensions and tolerances apply to the material immediately after cutting and perforating.

AMERICAN STANDARD For 16 mm Sound Film	ASA Z22.13 1941
CAMERA APERTURE	



	Millimeters	Inch Equivalents
A	10.41 ± 0.05	0.410 ± 0.002
B	7.47 ± 0.05	0.294 ± 0.002
C	8.00 ± 0.05	0.315 ± 0.002
D	0.15	0.006
E	0.05	0.002
F	2.79	0.110
R	0.5 approx.	0.02 approx.
$a = b = 1/2$ longitudinal perforation pitch.		

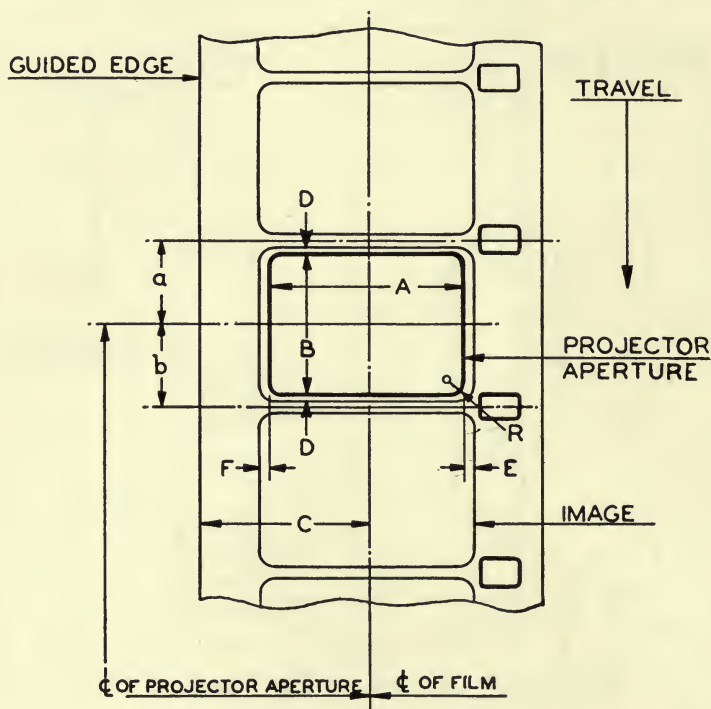
These dimensions and locations are shown relative to unshrunk raw stock.

The center of the frame-line shall pass through the center of a perforation.

AMERICAN STANDARD  
For 16 mm Sound Film

ASA  
Z22.14  
1941

PROJECTOR APERTURE



	Millimeters	Inch Equivalents
<i>A</i>	9.65 ± 0.05	0.380 ± 0.002
<i>B</i>	7.21 ± 0.05	0.284 ± 0.002
<i>C</i>	8.00 ± 0.05	0.315 ± 0.002
<i>D</i>	0.13	0.005
<i>E</i>	0.38	0.015
<i>F</i>	0.38	0.015
<i>R</i>	0.5 approx.	0.02 approx.

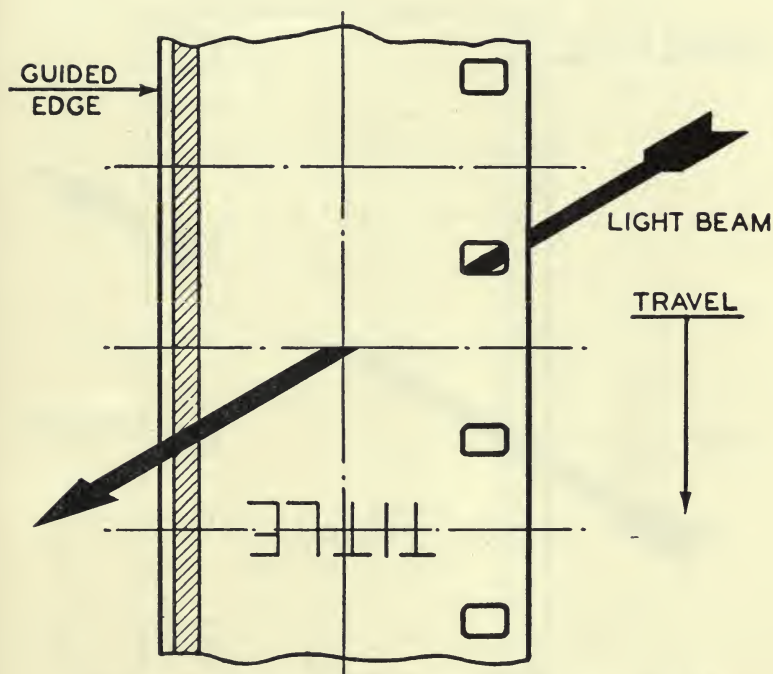
$a = b = \frac{1}{2}$  longitudinal perforation pitch.

These dimensions and locations are shown relative to unshrunk raw stock.

The center of the frame-line shall pass through the center of a perforation.



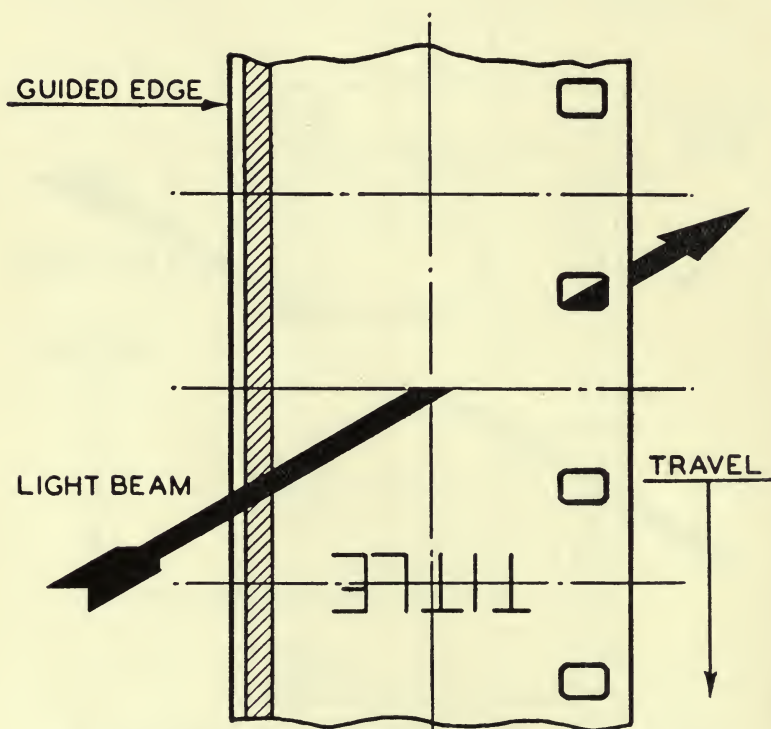
AMERICAN STANDARD For 16 mm Sound Film	ASA Z22.15 1941
EMULSION AND SOUND RECORD POSITIONS IN CAMERA—NEGATIVE	



*Drawing shows film as seen from inside the camera looking toward the camera lens.*

- (1) Emulsion position in camera: *toward the lens, except for special processes.*
- (2) Speed: 24 frames per second.
- (3) Distance between center of picture and corresponding sound: 26 frames.

AMERICAN STANDARD For 16 mm Sound Film	ASA Z22.16 1941
EMULSION AND SOUND RECORD POSITIONS IN PROJECTOR—POSITIVE For Direct Front Projection	



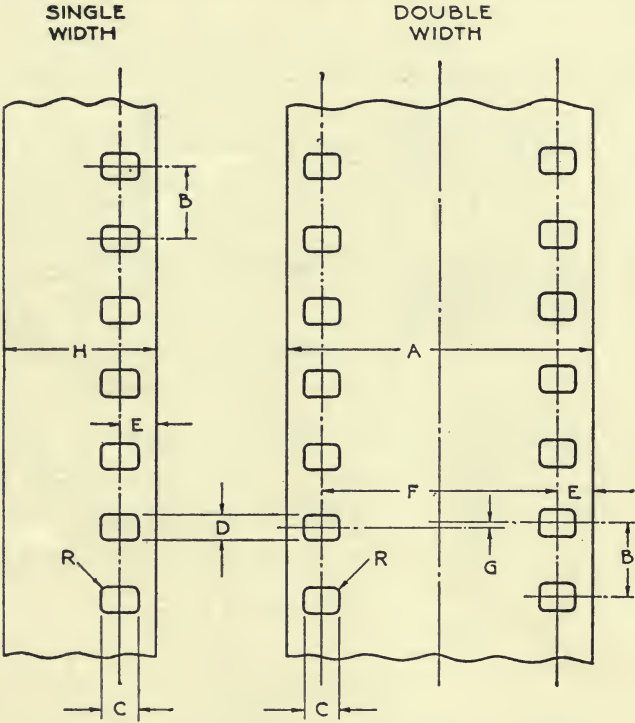
*Drawing shows film as seen from the light-source in the projector.*

- (1) Emulsion position in projector: *toward the lens, except for special processes.*
- (2) Speed: 24 frames per second.
- (3) Distance between center of picture and corresponding sound: 26 frames.

AMERICAN STANDARD  
For 8 mm Film

ASA  
Z22.17  
1941

CUTTING AND PERFORATING  
NEGATIVE AND POSITIVE RAW STOCK



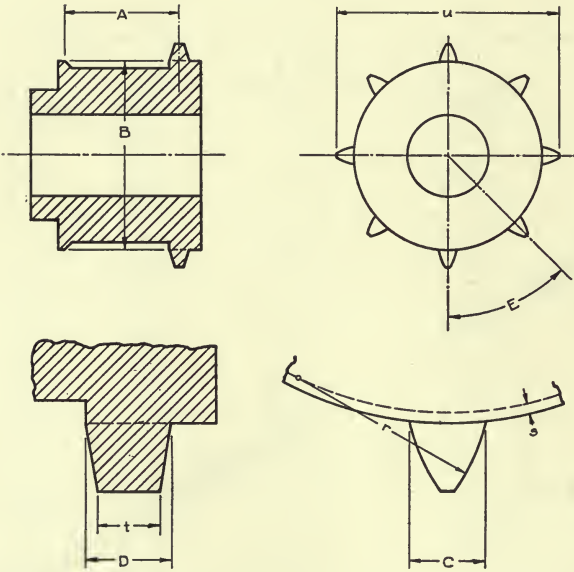
	Millimeters	Inch Equivalents
A	16.00 + 0.00 - 0.05	0.630 + 0.000 - 0.002
B	3.810 ± 0.013	0.150 ± 0.0005
C	1.83 ± 0.01	0.072 ± 0.0004
D	1.27 ± 0.01	0.0500 ± 0.0004
E	1.83 ± 0.05	0.072 ± 0.002
F	12.320 ± 0.025	0.485 ± 0.001
G	Not > 0.025	Not > 0.001
H	8.00 + 0.00 - 0.08	0.315 + 0.000 - 0.003
L*	381.00 ± 0.38	15.000 ± 0.015
R	0.25	0.010

\* L = the length of any 100 consecutive perforation intervals.

These dimensions and tolerances apply to the material immediately after cutting and perforating.  
Film may be slit before or after processing.

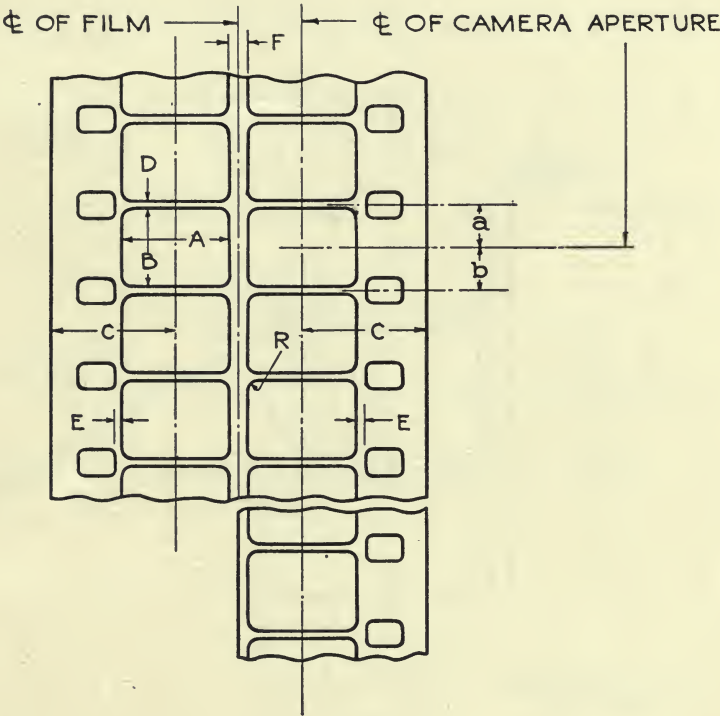


AMERICAN STANDARD For 8 mm Film		ASA Z22.18 1941
8-TOOTH PROJECTOR SPROCKETS		



	Millimeters	<i>Inch Equivalents</i>
A	5.72 ± 0.03	0.225 ± 0.001
B	9.42 + 0.00 - 0.05	0.371 + 0.000 - 0.002
C	1.02 + 0.00 - 0.05	0.040 + 0.000 - 0.002
D	1.14 + 0.08 - 0.00	0.045 + 0.003 - 0.000
E	45°0' ± 0.5'	
<i>Recommended Practice</i>		
r	2.54	0.100
s	0.13	0.005
t	0.51	0.020
u	11.33	0.450

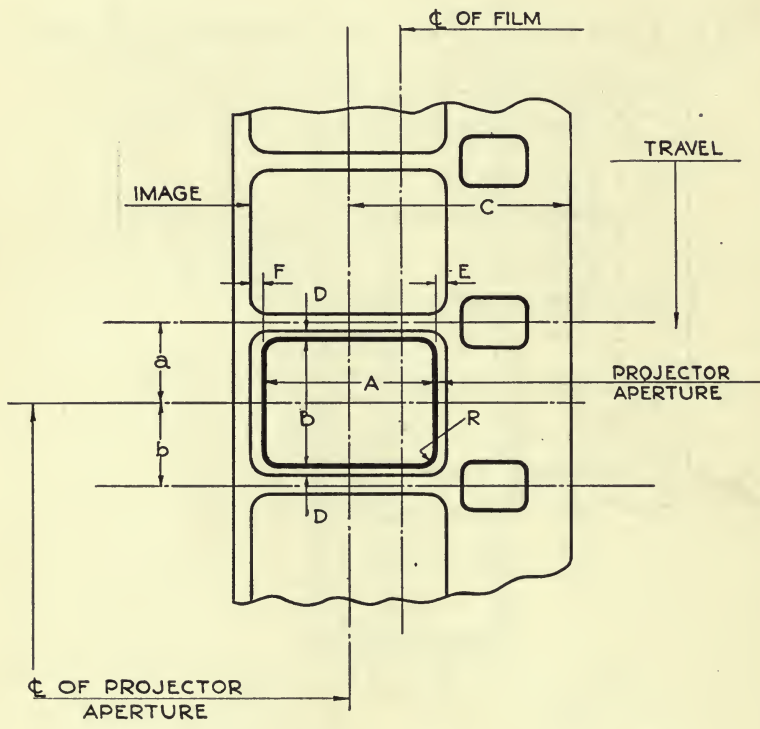
AMERICAN STANDARD For 8 mm Silent Film		ASA
		Z22.19
CAMERA APERTURE		1941



	Millimeters	Inch Equivalents
A	4.80 ± 0.03	0.189 ± 0.001
B	3.51 ± 0.03	0.138 ± 0.001
C	5.22 ± 0.05	0.205 ± 0.002
D	0.30	0.012
E	0.08	0.003
F	0.76	0.030
R	0.25	0.010

$a = b = \frac{1}{2}$  longitudinal perforation pitch.

AMERICAN STANDARD For 8 mm Silent Film	ASA Z22.20 1941
PROJECTOR APERTURE	

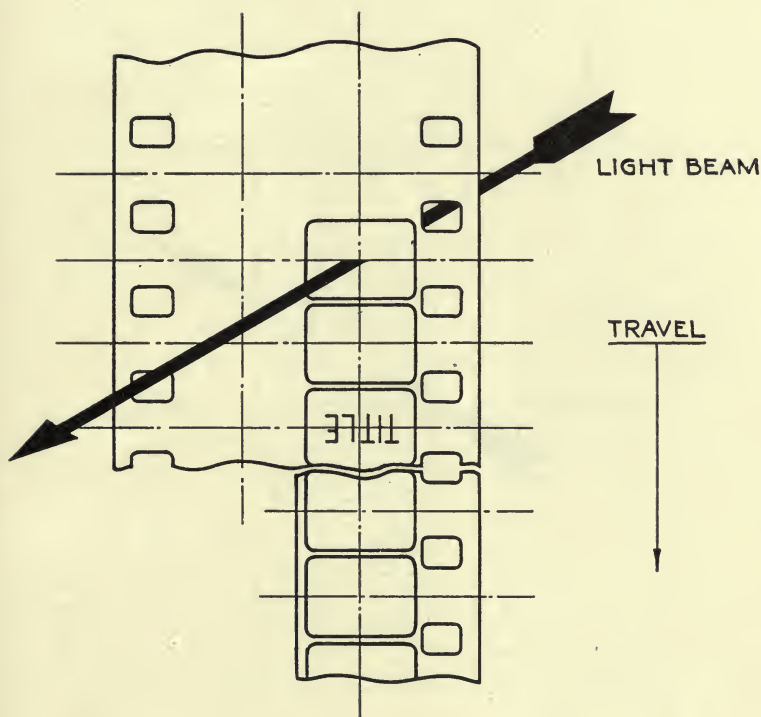


	Millimeters	Inch Equivalents
A	4.37 ± 0.03	0.172 ± 0.001
B	3.28 ± 0.03	0.129 ± 0.001
C	5.22 ± 0.05	0.2055 ± 0.002
D	0.11	0.004
E	0.21	0.008
F	0.21	0.008
R	0.25	0.010

$a = b = 1/2$  longitudinal perforation pitch.



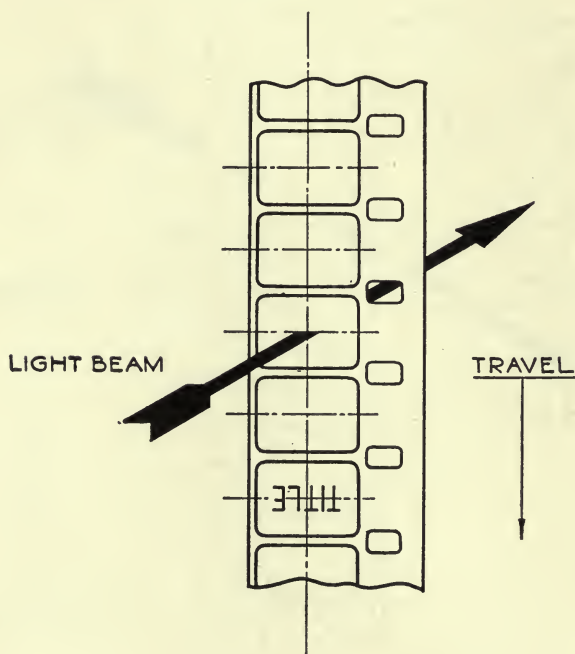
AMERICAN STANDARD For 8 mm Silent Film	ASA Z22.21 1941
EMULSION POSITION IN CAMERA-NEGATIVE	



*Drawing shows film from inside the camera, looking toward the camera lens.*

- (1) Emulsion position in camera: *toward the lens, except for special processes.*
- (2) Normal speed: 16 frames per second.

AMERICAN STANDARD For 8 mm Silent Film	ASA Z22.22 1941
EMULSION POSITION IN PROJECTOR— POSITIVE For Direct Front Projection	



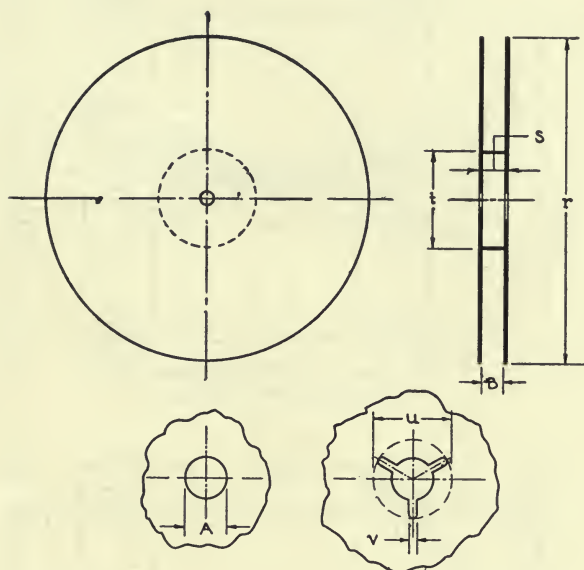
*Drawing shows film as seen from the light-source in the projector.*

- (1) Emulsion position in projector: *toward the lens, except for special processes.*
- (2) Normal speed: 16 frames per second.

AMERICAN STANDARD  
For 8 mm Silent Film

ASA  
Z22.23  
1941

PROJECTION REELS



Capacity, 60 M. (200 Ft.)		
	Millimeters	Inch Equivalents
A	$8.10 \pm 0.00$ $- 0.08$	$0.319 \pm 0.000$ $- 0.003$
B	8.9 Min.	0.35 Min.
Recommended Practice		
r	127.0	5.00
s	10.5	0.41
t	37.8	1.49
u	16.0	0.63
v	1.6	0.06

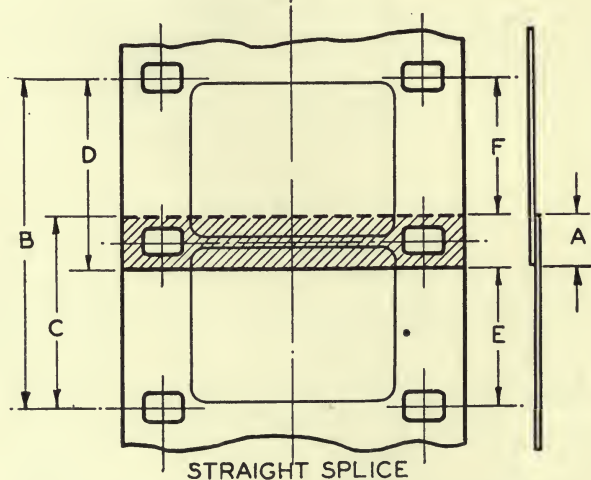
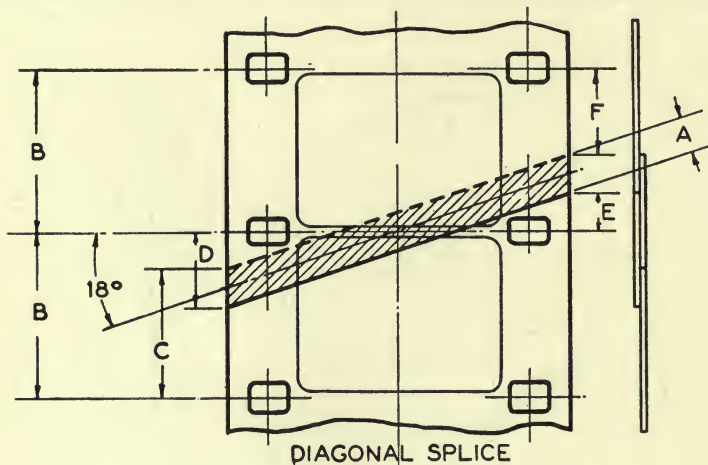
Drive side of sprocket may have any desired odd number of driving slots, evenly spaced.



AMERICAN RECOMMENDED PRACTICE  
For 16 mm Silent Film

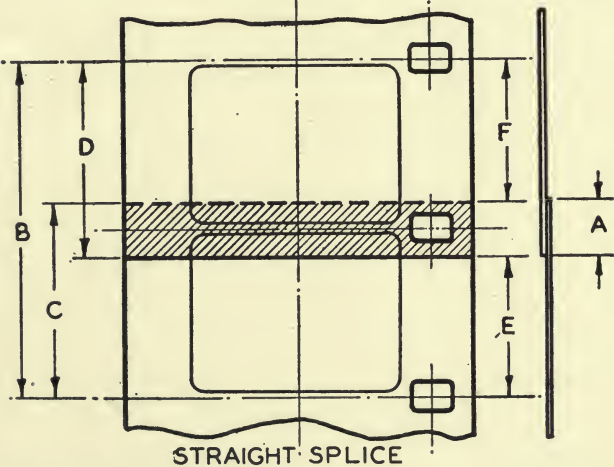
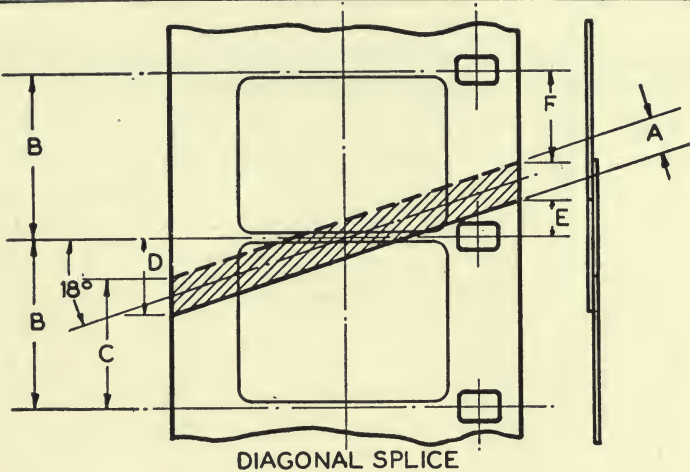
FILM SPLICES  
NEGATIVE AND POSITIVE

ASA  
Z22.24  
1941



	Diagonal		Straight	
	Mm.	Inch Equiv.	Mm.	Inch Equiv.
A	1.78	0.070	2.54	0.100
B	7.62	0.300	15.24	0.600
C	5.97	0.235	8.89	0.350
D	3.53	0.139	8.89	0.350
E	1.65	0.065	6.35	0.250
F	4.09	0.161	6.35	0.250

AMERICAN RECOMMENDED PRACTICE For 16 mm Sound Film	ASA Z22.25 1941
FILM SPLICES NEGATIVE AND POSITIVE	



	Diagonal		Straight	
	Mm.	Inch Equiv.	Mm.	Inch Equiv.
A	1.78	0.070	2.54	0.100
B	7.62	0.300	15.24	0.600
C	5.97	0.235	8.89	0.350
D	3.53	0.139	8.89	0.350
E	1.65	0.065	6.35	0.250
F	4.09	0.161	6.35	0.250

<p>AMERICAN RECOMMENDED PRACTICE FOR SENSITOMETRY</p>	<p>ASA Z22.26 1941</p>
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The principle of non-intermittency shall be adopted as recommended practice in making sensitometric measurements.



AMERICAN RECOMMENDED PRACTICE  
FOR  
PHOTOGRAPHIC DENSITY

ASA  
Z22.27  
1941

The integrating sphere shall be used as a primary instrument for the determination of photographic density. Photographic densities determined by means of this primary instrument shall be used as secondary or reference standards by means of which densitometers of other types may be calibrated.

AMERICAN RECOMMENDED PRACTICE FOR PROJECTION ROOMS	ASA Z22.28 1941
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*Projection Lens Height.*—The standard height from the floor to the center of the projection lens of a motion picture projector should be 48 inches.

*Projection Angle.*—Should not exceed 12 degrees.

*Observation Port.*—Should be 12 inches wide and 14 inches high, and the distance from the floor to the bottom of the openings shall be 48 inches. The bottom of the opening should be splayed 15 degrees downward. If the thickness of the projection room wall should exceed 12 inches, each side should be splayed 15 degrees.

*Projection Lens Mounting.*—The projection lens should be so mounted that the light from all parts of the aperture shall traverse an uninterrupted part of the entire surface of the lens.

*Projection Lens Focal Length.*—The focal length of motion picture projection lenses should increase in  $\frac{1}{4}$ -inch steps up to 8 inches, and in  $\frac{1}{2}$ -inch steps from 8 to 9 inches.

*Projection Objectives, Focal Markings.*—Projection objectives should have the equivalent focal length marked thereon in inches, quarters, and halves of an inch, or in decimals, with a plus (+) or minus (−) tolerance not to exceed 1 per cent of the designated focal length also marked by proper sign following the figure.

AMERICAN RECOMMENDED PRACTICE  
FOR  
PROJECTION SCREENS

ASA  
Z22.29  
1941

Sizes of screens shall be in accordance with the table below.

The spacing of grommets shall be 6 inches, with 12 inches as a possible sub-standard. The ratio of width to height of screens shall be 4 to 3.

The width of the screen should be equal to approximately  $\frac{1}{6}$  the distance from the screen to the rear seats of the auditorium. The distance between the front row of seats and the screen should be not less than 0.87 foot for each foot of screen width.

Screen Sizes

Size No. of Screen	Picture Width (Feet)	Picture Feet	Height, Inches	Size No. of Screen	Picture Width (Feet)	Picture Feet	Height, Inches
8	8	6	0	25	25	18	9
9	9	6	9	26	26	19	6
10	10	7	6	27	27	20	3
11	11	8	3	28	28	21	0
12	12	9	0	29	29	21	9
13	13	9	9	30	30	22	6
14	14	10	6	31	31	23	3
15	15	11	3	32	32	24	0
16	16	12	0	33	33	24	9
17	17	12	9	34	34	25	6
18	18	13	6	35	35	26	3
19	19	14	3	36	36	27	0
20	20	15	0	37	37	27	9
21	21	15	9	38	38	28	6
22	22	16	6	39	39	29	3
23	23	17	3	40	40	30	0
24	24	18	0				



AMERICAN RECOMMENDED PRACTICE FOR NOMENCLATURE	ASA Z22.30 1941
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*Number of Teeth in Mesh.*—The number of teeth in mesh with the film (commonly referred to as “teeth in contact”) shall be the number of teeth in the arc of contact of the film with the drum of the sprocket when the pulling face of one tooth is at one end of the arc.

AMERICAN RECOMMENDED PRACTICE	ASA
FOR	Z22.31
SAFETY FILM	1941

*Safety Film.*—The term “Safety Film,” as applied to motion picture materials, shall refer to materials having a burning time greater than 10 seconds and falling into the following classes: (a) support coated with emulsion, (b) any other material upon which or in which an image can be produced, (c) the processed products of these materials, and (d) uncoated support that is or can be used for motion picture purposes in conjunction with the aforementioned classes of materials.

The burning time is defined as the time in seconds required for the complete combustion of a sample of the material 36 inches long, the determination being according to the procedure of the Underwriters Laboratory. This definition was designed specifically to define Safety Film in terms of the burning rate of the commercial product of any thickness or width used in practice. The test of burning time, therefore, shall be made with a sample of the material in question having a thickness and width at which the particular material is used in practice.

All 16 and 8-mm film must be of the safety type.

AMERICAN RECOMMENDED PRACTICE FOR FADER SETTING INSTRUCTIONS	ASA Z22.32 1941
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The Fader Setting Instruction Leader shall consist of 15 frames located in the first 20 frames of the synchronizing leader; the first frame shall designate the type of print; the second frame the type of reproducing equipment necessary to project the print; and the next nine frames the general fader setting specified in relation to an average fader setting for the particular product under consideration. The remaining frames may be used for whatever additional information the studio may wish to transmit to the theater.

The designation "Regular" in the Instruction Leader indicates that only one type of print has been issued on the particular production under consideration. Productions with prints designated as either "Hi-Range" or "Lo-Range" are issued in both types of prints, *i. e.*, all productions on "Hi-Range" prints will have necessarily been issued on "Lo-Range" prints as well.

Both the terms "push-pull" and "single" shall be on every leader, one or the other being crossed out to leave the proper term designating the type of sound-track on the print.



HI-RANGE	LO-RANGE	LO-RANGE	REGULAR	REGULAR
SINGLE PUSH-PULL TRACK	SINGLE PUSH-PULL TRACK	SINGLE PUSH-PULL TRACK	SINGLE PUSH-PULL TRACK	SINGLE PUSH-PULL TRACK
PLAY	PLAY	PLAY	PLAY	PLAY
SOUND	SOUND	SOUND	SOUND	SOUND
8 EIGHT	3 THREE	AT	3 THREE	AT
OR	OR	<i>Insert Studio Name</i>	OR	<i>Insert Studio Name</i>
9 NINE	4 FOUR	AVERAGE	4 FOUR	AVERAGE
OR	db	FADER	db	FADER
ABOVE	ABOVE	SETTING	ABOVE	SETTING
<i>Insert Studio Name</i>	<i>Insert Studio Name</i>	FOR THIS	<i>Insert Studio Name</i>	FOR THIS
AVERAGE	AVERAGE	THEATRE	AVERAGE	THEATRE

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**AMERICAN RECOMMENDED PRACTICE  
FOR  
NOMENCLATURE FOR FILTERS**

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**ASA  
Z22.33  
1941**

The symbol describing any filter shall consist of three characters, the first designating the frequency of 3-db insertion loss, the second the character "Hi" or "Lo" to indicate high-pass or low-pass, and the third the frequency of 10-db insertion loss (all frequencies in cycles).

Thus the following describes several low-pass filters "4000 Lo 6000" (Fig. 1), "5000 Lo 7000" or "4500 Lo 5500" and the following describe several high-pass filters: "60 Hi 40" (Fig. 2), "80 Hi 30," or "100 Hi 50."

A combination of two of the above symbols may be used to describe a band-pass filter (Fig. 3) or a dividing network (Fig. 4) or a reverse combination of symbols may be used to describe a band-elimination filter (Fig. 5).

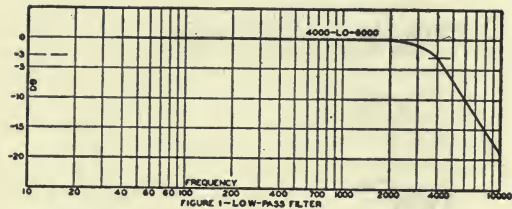


FIGURE 1—LOW-PASS FILTER

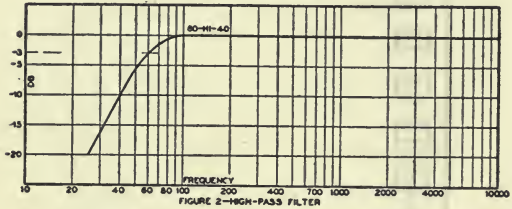


FIGURE 2—HIGH-PASS FILTER

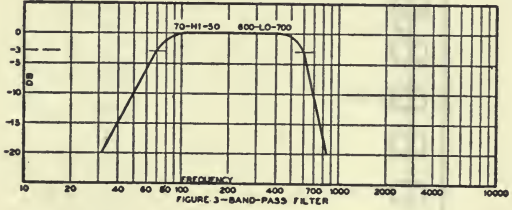


FIGURE 3—BAND-PASS FILTER

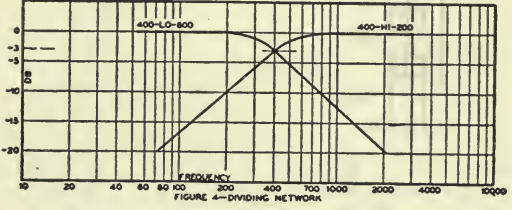


FIGURE 4—DIVIDING NETWORK

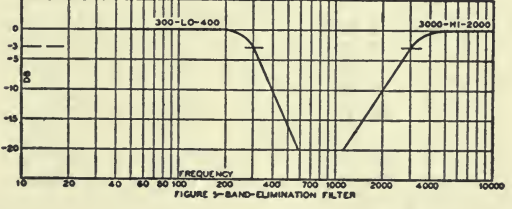


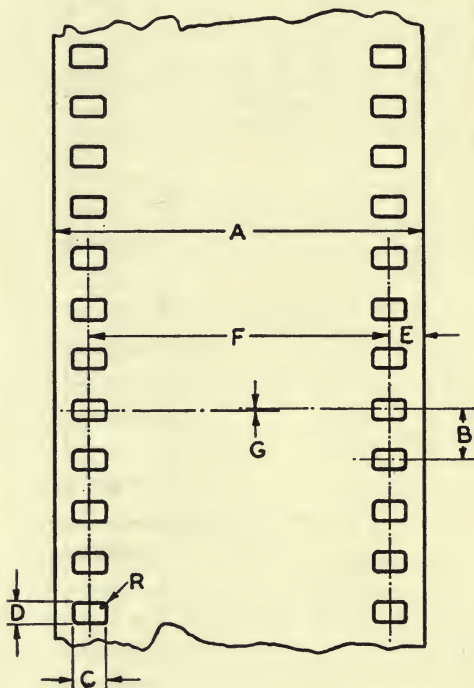
FIGURE 5—BAND-ELIMINATION FILTER



AMERICAN STANDARD  
For 35 mm Film

CUTTING AND PERFORATING  
NEGATIVE AND POSITIVE RAW STOCK

ASA  
Z22.34  
1930

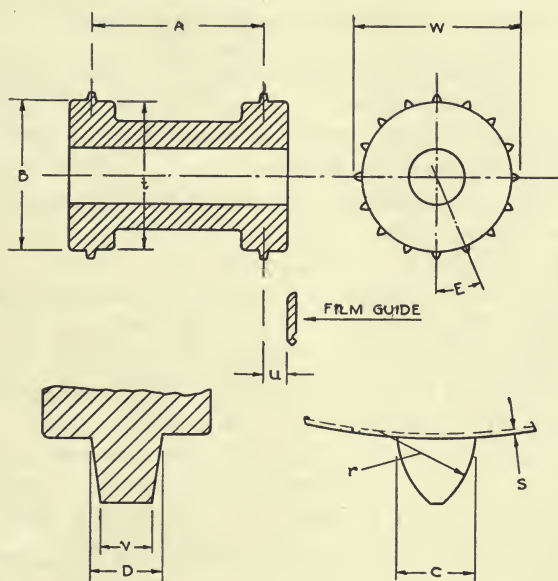


	Millimeters	Inch Equivalents
A	35.00 + 0.00 - 0.05	1.378 + 0.000 - 0.002
B	4.750 ± 0.013	0.1870 ± 0.0005
C	2.794 ± 0.01	0.1100 ± 0.0004
D	1.98 ± 0.01	0.0780 ± 0.0004
E	3.40 ± 0.05	0.134 ± 0.002
F	28.17 ± 0.05	1.109 ± 0.002
G	Not > 0.025	Not > 0.001
L*	475.00 ± 0.38	18.700 ± 0.015
R	0.5	0.020

\* L = the length of any 100 consecutive perforation intervals.

These dimensions and tolerances apply to the material immediately after cutting and perforating.

AMERICAN STANDARD For 35 mm Film	ASA Z22.35 1930
16-TOOTH PROJECTOR SPROCKETS	



Feed Sprocket			Intermittent Sprocket		Take-Up(Hold-Back) Sprocket	
Millimeters		Inch Equivalents	Millimeters	Inch Equivalents	Millimeters	Inch Equivalents
A	27.36 ± 0.03	1.097 ± 0.001	27.86 ± 0.03	1.097 ± 0.001	27.86 ± 0.03	1.097 ± 0.001
B	24.00 ± 0.03	0.945 ± 0.001	24.00 ± 0.005	0.945 ± 0.0002	23.67 ± 0.03	0.932 ± 0.001
C	1.40 + 0.00 - 0.05	0.055 + 0.000 - 0.002	1.40 + 0.00 - 0.05	0.055 + 0.000 - 0.002	1.40 + 0.00 - 0.05	0.055 + 0.000 - 0.002
D	1.40 ± 0.00 - 0.05	0.055 ± 0.000 - 0.002	1.40 + 0.00 - 0.05	0.055 ± 0.000 - 0.002	1.40 + 0.00 - 0.05	0.055 ± 0.000 - 0.002
E	22 Deg. 30 Min. ± 1.5 Min.		22 Deg. 30 Min. ± 0.75 Min.*		22 Deg. 30 Min. ± 1.5 Min.	
Recommended Practice						
r	1.96	0.077	1.96	0.077	1.96	0.077
s	0.10	0.004	0.10	0.004	0.10	0.004
t	23.75	0.935	23.75	0.935	23.42	0.922
u	3.53	0.139	3.53	0.139	3.53	0.139
v	1.02	0.040	1.02	0.040	1.02	0.040
w	26.54	1.045	26.54	1.045	26.21	1.032

\* The accumulated error between any two teeth not to exceed 4 minutes.

## INFORMATIONAL DATA

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UNIT OF PHOTOGRAPHIC INTENSITY	
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While no standard or recommended practice for a unit of photographic intensity is proposed at this time, the description of an international unit of photography as adopted by the International Congress of Photography in 1928 and 1931 is here given as a matter of information. The resolution passed by the 1928 Congress defining the unit of photographic intensity received the approval of the English and American national committees and of the Optical Society of America. At the 1931 Congress an amendment to the resolution passed by the 1928 Congress was proposed and accepted by the representatives of the various national committees in attendance. So far as can be determined, no official approval by the various national committees was subsequently given. There is therefore a little doubt as to the exact status of this standard as established by the International Congress. The ASA Sectional Committee Z22, Motion Pictures, is at the present time in active coöperation with the ASA Sectional Committee Z38, Photography, in an endeavor to clarify this matter and to formulate a proposal for an American standard for a unit of photographic intensity.

The unit of photographic intensity for the sensitometry of negative materials may be defined as the intensity of a filtered source of radiation having a luminous intensity of one international candle, and produced by a gray body at a color temperature of 2380° (according to the most recent determination of the international temperature scale), together with a selectively absorbing filter made up as follows: Two solutions compounded according to the following formula, the complete filter to consist of a 1-cm\* layer of each solution contained in a double cell made by using three pieces of borosilicate crown glass (refractive index,  $D = 1.51$ ), each 2.5 mm thick.

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\* Tolerance in thickness shall be  $\pm 0.05$  mm.



*Solution A*

Copper sulfate, ( $\text{CuSO}_4, 5\text{H}_2\text{O}$ )	3.707 gm*
Mannite, ( $\text{C}_6\text{H}_8(\text{OH})_6$ )	3.707 gm*
Pyridine, ( $\text{C}_5\text{H}_5\text{N}$ )	30.0 cc
Water (distilled) to make	1000. cc

*Solution B*

Cobalt ammonium sulphate, ( $\text{CoSO}_4, (\text{NH}_4)_2\text{SO}_4, 6\text{H}_2\text{O}$ )	26.827 gm*
Copper sulfate, ( $\text{CuSO}_4, 5\text{H}_2\text{O}$ )	27.180 gm*
Sulfuric acid (sp. gr. 1.835)	10.0 cc
Water (distilled) to make	1000. cc

The spectrophotometric absorption characteristics of the filter made up according to these specifications are shown in the following chart,\*\* and in the table below this information is given in numerical form.

The unit of photographic intensity as recommended by the Seventh International Congress of Photography, held in London in July, 1928, was formally approved by the English and American Committees of the Congress and by the Optical Society of America. In ratifying this standard, the Optical Society of America, in order to forestall any possible misinterpretation of the intent of the resolution, presented the following clarifying statements:

"In ratifying this proposal the Optical Society of American understands that the intent of this recommendation is as follows:

(1) The intention is to specify two things, (a) the unit in which the intensities of light-sources are to be expressed, and (b) the quality of light to be used.

(2) The unit is to be the International Candle, implying further that the intensities measured and stated will be luminous intensities as in visual photometry.

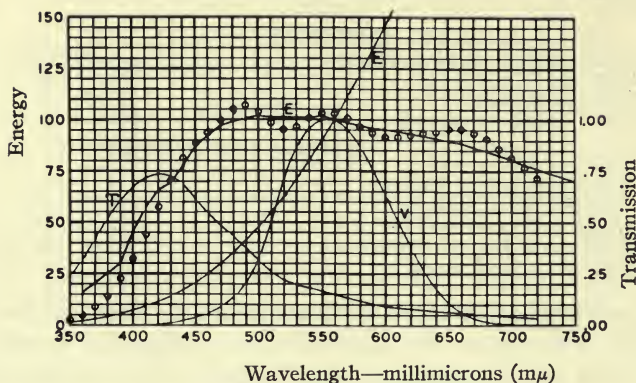
(3) The quality of light to be used for sensitometry of negative materials is to be that which results from passing the radiation from a gray body at 2380°K normally through the filter described.

(4) The gray body and the selectively absorbing filter together shall be considered as the effective source in specifying the intensity (candle-power).

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\* For practical purposes an accuracy to the second place of decimals is probably sufficient.

\*\* *Bur. Standards Misc. Publ. No. 114*: Raymond Davis and K. S. Gibson, "Filters for the Reproduction of Sunlight and Daylight, and the Determination of Color-Temperature."



$\lambda$ (mμ)	$T$	$E''^*$	$E''/E'$	$\gamma$ (mμ)	$T$	$E''^*$	$E''/E'$
350	0.230	2.5	...	40	0.182	100.6	0.997
60	0.321	4.9	0.304	550	0.167	103.2	1.014
70	0.420	8.7	0.426	60	0.1495	103.1	1.031
80	0.518	14.5	0.579	70	0.1316	100.4	1.021
90	0.608	22.5	0.749	80	0.1151	96.9	0.997
400	0.671	32.3	0.715	90	0.1013	93.4	0.977
10	0.714	44.0	0.767	600	0.0907	91.3	0.959
20	0.737	57.4	0.871	10	0.0834	91.2	0.968
30	0.725	70.3	1.016	20	0.0778	92.3	0.991
40	0.682	81.2	1.044	30	0.0730	93.3	1.012
450	0.612	88.6	1.021	40	0.0684	94.0	1.032
60	0.540	93.9	1.018	650	0.0646	95.1	1.060
70	0.483	99.9	1.031	60	0.0605	95.1	1.074
80	0.431	105.0	1.060	70	0.0558	93.4	1.081
90	0.376	107.1	1.065	80	0.0510	90.5	1.069
500	0.315	103.9	1.020	90	0.0457	85.8	1.038
10	0.259	98.3	0.972	700	0.0409	81.2	1.008
20	0.219	95.0	0.939	10	0.0366	76.4	0.979
30	0.197	96.7	0.957	20	0.0326	71.6	0.940

$T$ —Spectral Transmission of Filter at 25°C

$V$ —Relative Visibility Function

$E$ —Relative Energy of 2360°K

$E'$ —Relative Energy of Mean Noon Sunlight at Washington

$E'' (= T \times E)^*$ —Relative Energy of 2380°K and Filter Combination  
Light Transmission of Filter  
for 2380°K = 0.1352\*\*

\* Adjusted to make sum of  $E'' - E'$  from 400 to 720 mμ equal practically to zero.

\*\* Factor to be used to multiply the candle-power of the light-source to obtain the candle-power of the source-and-filter combination.

(5) The procedure recommended for determining the intensity of the combined effective source is to multiply the intensity of the primary source (gray body) by the appropriate transmission factor of the filter which is 0.135. This factor has been computed from the spectral transmission of the filter *via* the relative energy distribution of 2380°K and the relative visibility function adopted by the sixth session of the International Commission on Illumination at Geneva, 1924.

(6) This resolution does not state or imply the value of illumination to be used at the test plane during the sensitometric exposure, nor does it place any limitations on the intensity of the light-source to be used.

Pyridine as included in Solution *A* can, in the opinion of various scientific groups which have investigated the matter, be obtained commercially of sufficient purity to obviate the need for any elaborate precautions and to permit its satisfactory inclusion in the formula for Solution *A*.



## REPORT OF THE SMPE STANDARDS COMMITTEE

**Summary.**—*Proposals of specifications for (1) 35-mm and 16-mm raw-stock cores, (2) for screen brightness, (3) for rescinding the lantern-slide specifications previously included among the SMPE Recommended Practices, and (4) specifications for cutting and perforating 35-mm positive raw-stock and negative raw-stock have received initial approval of the SMPE Standards Committee in meeting and final approval by letter-ballot of the entire Standards Committee membership. The specifications were approved by the Board of Governors on January 24, 1941, and therefore are now Recommended Practices of the SMPE. This approval by the Board of Governors is in accord with the new standardization procedure for the Standards Committee also adopted by the Board on the same date.*

**35-Mm and 16-Mm Raw-Stock Cores.**—In the Report of the Standards Committee published in the January, 1940, issue of the JOURNAL were included proposed specifications for 16-mm raw-stock cores, after approval by letter-ballot of the SMPE Standards Committee. Similar approval by letter-ballot has since been obtained on the specifications for 35-mm raw-stock cores. For convenience of reference, the two sets of specifications are reproduced on the following two pages.

**Screen Brightness.**—The previous SMPE Recommended Practice for screen brightness, published in the March, 1938, issue of the JOURNAL indicated 7 to 14 ft-lamberts at the center of the screen, when the projector was running with no film in the gate. The recently approved specifications, contained on a following page, changes this range of brightness to  $10^{+4}_{-1}$  ft-lamberts.

**Lantern-Slides.**—The previous specifications for the mat opening of lantern-slides were given in the March, 1938, issue of the JOURNAL on p. 255. Letter-ballot of the Standards Committee has recently given final approval to rescinding these specifications and to omit entirely from the SMPE Recommended Practices any specification for lantern-slides.

**Cutting and Perforating 35-Mm Positive Raw-Stock and Negative Raw-Stock.**—Previous specifications for 35-mm negative and positive raw-stock were contained in a single drawing published in the March, 1938, issue of the JOURNAL on p. 261, including the same perforation for both negative and positive film. After several years of trial of

the single perforation, the Standards Committee, by letter-ballot, has approved the adoption of different perforations for positive and negative raw-stocks. The specifications are given on two following pages.

If after thirty days from the date of publication of this issue of the JOURNAL, no adverse comments are received by the Chairman of the Standards Committee from the membership of the Society with regard to these four items, the specifications described herein will be referred to the Board of Governors of the Society for action upon them as proposals for either American Standards or Recommended Practices. Comments on these proposals are invited from readers of the JOURNAL.

*D. B. JOY, Chairman*

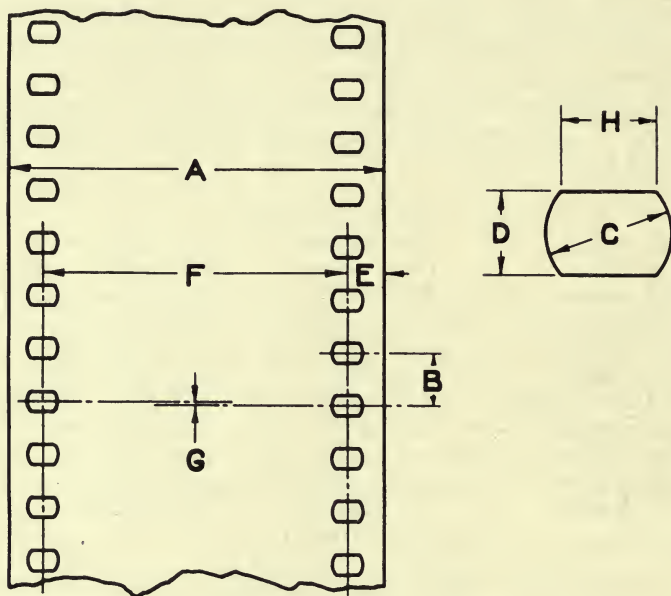
P. H. ARNOLD	A. F. EDOUART	K. F. MORGAN
H. BAMFORD	J. L. FORREST	R. MORRIS
M. C. BATSEL	G. FRIEDL, JR.	WM. H. OFFENHAUSER
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L. W. DAVEE	C. L. LOOTENS	J. L. SPENCE
J. A. DUBRAY	J. A. MAURER	H. E. WHITE
	G. S. MITCHELL	

*(Please turn to next page.)*

SMPE RECOMMENDED PRACTICE  
For 35-mm Film

CUTTING AND PERFORATING  
NEGATIVE RAW STOCK\*

SMPE  
January, 1941



	Millimeters	Inch Equivalents
A	35.00 $\pm$ 0.00 - 0.05	1.378 $\pm$ 0.000 - 0.002
B	4.75 $\pm$ 0.013	0.1870 $\pm$ 0.0005
C**	2.794 $\pm$ 0.01	0.1100 $\pm$ 0.0004
D	1.85 $\pm$ 0.01	0.0730 $\pm$ 0.0004
E	3.40 $\pm$ 0.05	0.134 $\pm$ 0.002
F	28.17 $\pm$ 0.05	1.109 $\pm$ 0.002
G	Not $>$ 0.025	Not $>$ 0.001
H	2.08 $\pm$ 0.025	0.082 $\pm$ 0.001
L†	475.00 $\pm$ 0.38	18.70 $\pm$ 0.015

\*\* Diameter of circle of curvature.

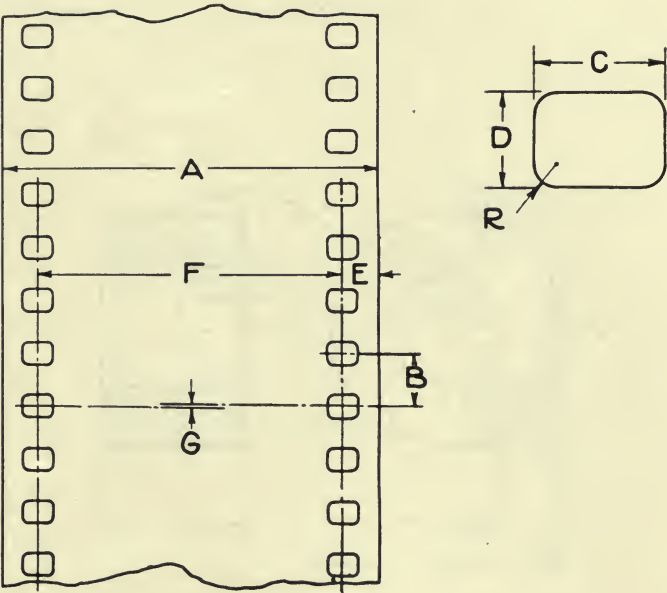
† L = length of any 100 consecutive perforation intervals.

\* For picture negative and certain special processes.

These dimensions and tolerances apply to the material immediately after cutting and perforating.



	SMPE RECOMMENDED PRACTICE For 35-mm Film	SMPE January, 1941
	CUTTING AND PERFORATING POSITIVE RAW STOCK*	



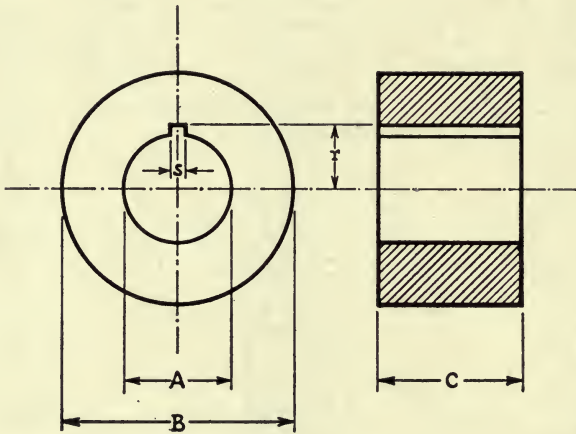
	Millimeters	Inch Equivalents
A	35.00 + 0.00 - 0.05	1.378 + 0.000 - 0.002
B	4.750 ± 0.013	0.1870 ± 0.0005
C	2.794 ± 0.01	0.1100 ± 0.0004
D	1.98 ± 0.01	0.0780 ± 0.0004
E	3.40 ± 0.05	0.134 ± 0.002
F	28.17 ± 0.05	1.109 ± 0.002
G	Not > 0.025	Not > 0.001
L**	475.00 ± 0.38	18.70 ± 0.015
R	0.5	0.020

\*\* L = length of any 100 consecutive perforation intervals.

\* For positive prints and sound recording.

These dimensions and tolerances apply to the material immediately after cutting and perforating.

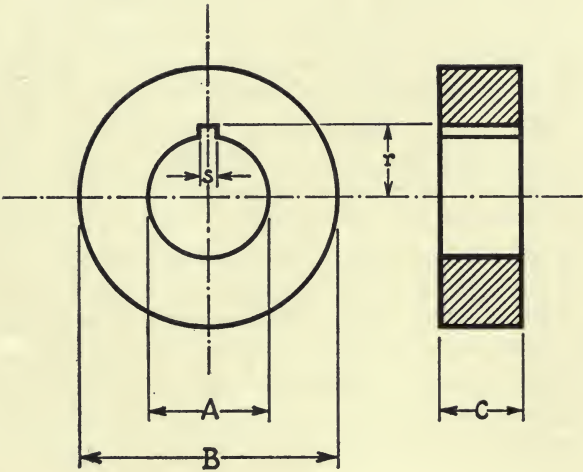
AMERICAN STANDARDS For 35-mm Film		SMPE January, 1941
RAW STOCK CORES		



	Millimeters	Inch Equivalents
<i>A</i>	25.90 ± 0.20	1.020 ± 0.008
<i>B</i>	50.00 ± 0.25	1.968 ± 0.010
<i>C</i>	34.50 ± 0.50	1.358 ± 0.020
Recommended Practice		
<i>r</i>	16.70 ± 0.30	0.657 ± 0.012
<i>s</i>	4.00 ± 0.20	0.157 ± 0.008

Bore *A* to fit freely to hub 25.40 ± 0.1 mm or 1.000 ± 0.004 inch diameter.

	SMPE Recommended Practice For 16-mm Film	SMPE January, 1941
	RAW STOCK CORES	



	Millimeters	Inch Equivalents
A	25.90 ± 0.20	1.020 ± 0.008
B	50.00 ± 0.25	1.968 ± 0.010
C	15.50 ± 0.50	0.610 ± 0.020
Recommended Practice		
r	16.70 ± 0.30	0.657 ± 0.012
s	4.00 ± 0.20	0.157 ± 0.008

Bore A to fit freely to hub 25.40 ± 0.1 mm or 1.000 ± 0.004 inch diameter.

	<b>SMPE RECOMMENDED PRACTICE</b> <b>For 35-mm Film</b>	<b>SMPE</b> <b>January, 1941</b>
	<b>PROJECTION SCREEN BRIGHTNESS</b>	

The brightness at the center of a screen for viewing 35-mm motion pictures shall be  $10^{+4}_{-1}$  ft-lamberts when the projector is running, with no film in the gate.



## THEATER ACOUSTIC RECOMMENDATIONS OF THE ACADEMY RESEARCH COUNCIL THEATER STANDARDIZATION COMMITTEE

These theater acoustic recommendations are based upon the experience of architects, acoustical and equipment engineers, and studio operating personnel in designing, equipping, and maintaining theaters. They were prepared after conferences and discussions between the Committee and prominent representatives of these various groups. Through such coöperation, it is now possible and practicable to formulate general principles to guide the acoustic design and construction of motion picture theaters. These principles, when applied, will improve sound reproduction and minimize or eliminate costly alterations in the completed auditorium.

In designing a theater auditorium, the architect is interested primarily in the usefulness and appearance of the finished structure. However, the auditorium shape, and the type, amount, and location of the necessary acoustic materials must guide in the construction and final appearance. From this point of view, some general considerations of acoustics will be outlined, and the application of these principles explained. In order to avoid misunderstandings, definitions of certain acoustical terms are given in an appendix.

### REQUIREMENTS FOR PROPER LISTENING CONDITIONS

The acoustical requirements for good listening conditions in an auditorium are that the sound loudness be adequate; that the components of the complex sound maintain their proper relations; and that the successive sounds in fast-moving speech or music be clear and distinct, and that the auditorium be free from extraneous noises. These fundamental concepts are both necessary and sufficient for good listening conditions.

These proper listening conditions are affected by the following physical factors:

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\* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received Dec. 20, 1940. (The Society is not responsible for statements by authors.)

- (1) Size of the room.
- (2) Shape of the room.
- (3) Absorption characteristics of the acoustic materials and their placement in the room.
- (4) Extraneous noise level present in the room.

#### THEORETICAL CONSIDERATIONS

As the optimum reverberation time of a room and the proper control of reflection effects are the two most important factors in proper acoustical design, a brief discussion of these factors follows:

*Optimum Reverberation Time.*—The desirable reverberation time of a room is a function of its size. The effect of moderate reverberation is beneficial as the direct sound is reinforced and a desirable liveness is produced. In general, a reverberation time of 2 seconds (at 500 cycles and under empty hall conditions) should not be exceeded. Excessive reverberation causes blurring of speech and

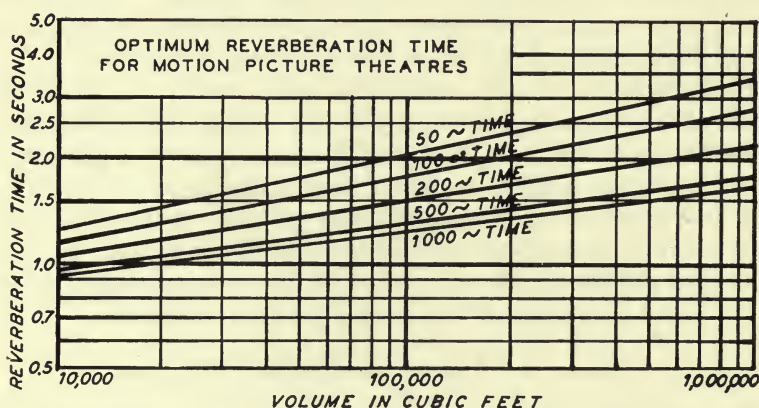


FIG. 1. Optimum reverberation time for motion picture theaters.

rapidly moving staccato music. Where the reverberation time in the room is below optimum, an excessive amount of sound energy must be radiated, and the resultant sound is unnatural.

The optimum reverberation period varies with frequency and with the size of the room. Fig. 1 gives the optimum reverberation time for various sizes of motion picture auditoriums at frequencies from 50 to 4000 cycles.

*Reflection Effects.*<sup>1</sup>—Many theaters still have many major acoustical defects due to their shapes and sizes which cause echoes and objectionable concentrations by a focusing of the reflected sound.

These reflections are in numerous cases of greater importance than the reverberation time.<sup>2</sup>

When a sound-wave strikes a wall of a theater, its energy is partially reflected, partially absorbed, and partially transmitted. The reflection, for surfaces large in comparison to the wavelength of the sound, is analogous to the reflection of light, and the angle of incidence of the sound is equal to the angle of reflection. The relative amounts of energy reflected and absorbed by a material vary with the angle of incidence and with the frequency.

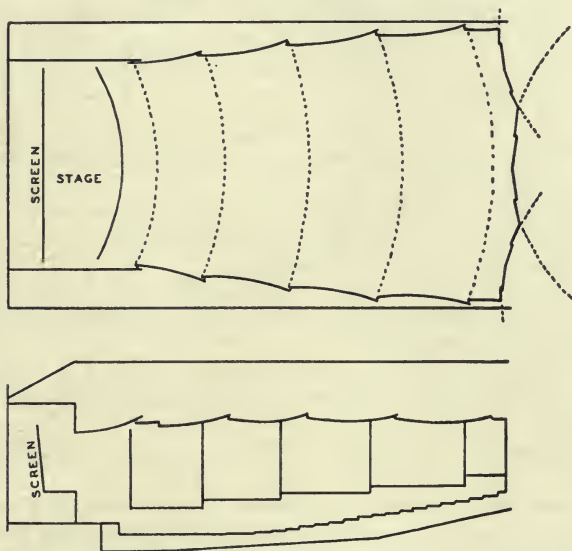


FIG. 2. A typical illustration of optimum acoustical design.

However, while a doubling in energy is the maximum increase or reinforcement which can take place at any one point, the decreased level or cancellation effect can be infinite. Consequently, any absorption at the point of reflection will tend to decrease the additive and subtractive components, and to minimize the modification of the characteristics of the direct sound.

*Control of Reflection Effects.*—For proper sound reflection control in an auditorium the acoustic treatment and shape of the walls and ceiling must be such as thoroughly to diffuse the reflected sound. In other words, the reflected energy received in any auditorium location should not come from one particular reflecting area but



should be contributed by numerous reflecting surfaces. The energy from any reflection should be small compared to the total reflected sound energy at any point in the auditorium.

This also provides a uniform logarithmic decay of the reverberant sound.<sup>3</sup> Little is gained by attempting to reinforce the direct sound by allowing maximum reflection to take place, as any small gain in sound energy may be overbalanced by destructive interference effects.

*Optimum Acoustical Design.*—Two of the most common defects of a theater, attributable to poor shape design, are echoes and sound concentrations.<sup>3</sup> These, as well as other defects, can be avoided, and the optimum characteristics obtained by observing the following general rules (see Fig. 2):

(1) The cubical contents should be kept to a minimum consistent with the number of seats required.

(2) The auditorium width should be from 50 to 70 per cent of the length, and the ceiling height not more than 40 per cent of the length.

(3) Non-parallel surfaces should be used.

(4) Convex, rather than concave, walls and ceiling sections should be provided. The wall and ceiling surfaces should also otherwise be broken up so as to diffuse the sound thoroughly.

(5) The average absorption per square-foot on the floor and ceiling should not be appreciably different from the average absorption per square-foot on the side walls.

(6) Well upholstered seats and ozite-lined carpet in the aisles should be provided.

(7) The backstage should be so shaped and so acoustically treated that resonant reinforcements of sound will not be reflected into the auditorium to distort sound quality.

It should be pointed out that the design in Fig. 2 is only one method of applying the above principles to obtain an ideal set-up. The fully convex rear wall and the convex sections on the side walls and ceiling are ideal design features, but a design including the three convex surfaces on the rear wall or a design as shown by the solid lines will also give excellent results.

These general rules will be explained in greater detail and illustrations given of good and faulty designs.

#### SIZE OF ROOM

*Optimum Volume.*—Both from an acoustical standpoint and in the interests of economy, the cubical content or volume of the auditorium



should be kept as small as possible, consistent with the required seating capacity and proper proportions of length, width, and height.

In small auditoriums it is possible to obtain optimum reverberation conditions without acoustic treatment on the walls and ceiling, provided the seats are fully upholstered, the aisles carpeted, and the auditorium properly designed to diffuse the sound reflections and to provide uniform loudness at every seat in the auditorium.

Recent acoustical design in which the volume has been held to a minimum, without sacrifice of other features, has provided one of the most outstanding improvements in general sound quality in the theater. From an average of recent trends in design giving satis-

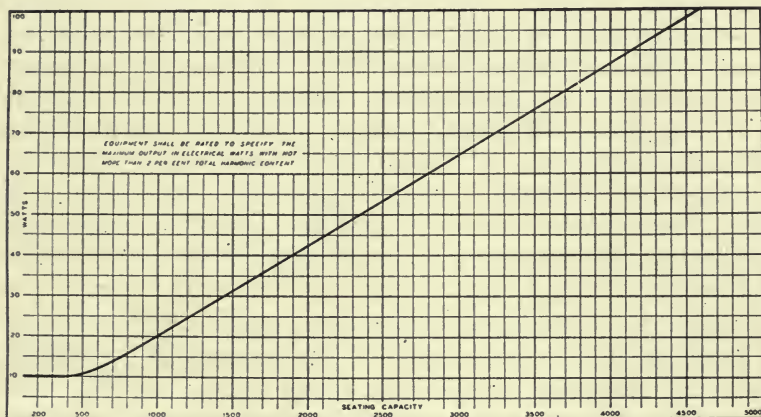


FIG. 3. Academy Research Council minimum power requirements for theaters; minimum recommended amplifier output based upon seating capacity of the auditorium.

factory performance, it has been determined that approximately 125 cubic-feet per seat is desirable for a medium-size house.<sup>4</sup> This figure varies with the seating capacity of the auditorium.

*Minimum Power Requirements for Theaters.*—The acoustical power necessary for proper sound reproduction varies with the volume of the auditorium. Minimum power requirements for theaters have been established by the Academy Research Council,<sup>5</sup> and are given in Fig. 3 in terms of amplifier watts installed.

#### SHAPE OF ROOM

*Recommended Auditorium Proportions.*—For some time a proportion of from 50 to 70 per cent between length and width has been

considered good.<sup>6</sup> The source of sound is at the end of the small dimension. In a room with non-parallel walls or of irregular contours, the above rule may be applied using the average width and length. In those rooms where the length is greater than twice the width, the reflections between the side walls cause serious damage to the quality.

As previously explained, excessively high rooms should be avoided; that is, the ceiling height should be kept to the minimum consistent with the seating capacity and other necessary architectural requirements.

*Side Walls.*—Flat parallel walls in auditoriums of all sizes have always been a distinct source of trouble from both a vision and sound standpoint. In such an auditorium seats installed in the front corner sections of the ground floor afford only a very distorted view of the picture and are unsatisfactory to the theater patron. From a sound standpoint, flat parallel surfaces give rise to disturbing sustained cross-reflection. A theater with a "fan-shaped" floor plan, as shown in Fig. 2, offers decided advantages over rectangular designs, as better vision is secured, and a basic shape is available which is easily accommodated to a side wall design giving proper diffusion and control of the reflected sound.<sup>7</sup>

Where it is not practicable to use convex side wall surfaces because of economic limitations or difficulties of providing proper lighting, the side walls should be broken up into sloping sections. These sections should be so angled with respect to the high-frequency horn as to reflect the sound well into the side rather than too much into the center of the audience.

*Auditorium Ceiling.*—The ceiling surface should not be parallel to the floor, as such a design results in acoustical deficiencies. As shown in Fig. 2, the ceiling should be designed to secure desirably directed reflections and to eliminate echoes. In all cases every effort should be made to avoid ceiling designs which involve domes or other concave types of construction which focus the sound into the seating area.

Lighting fixtures constructed with loosely held portions of glass or plastic materials should be avoided as such fixtures often rattle, being resonant at certain frequencies.

*Auditorium Floor.*—Well upholstered and heavily padded seats should be used in furnishing the auditorium. The aisles and corridors

should be covered with ozite-lined carpet. This reduces the variation in the reverberation time under different audience conditions.

With upholstered seats and carpeted aisles, it is generally not desirable to treat the ceiling acoustically. Such treatment results in an acoustic condition in which the reverberation time is shorter in the vertical direction; that is, shorter between the floor and the ceiling than between the side walls and the front and rear walls. For optimum acoustical conditions in a room, it is necessary that the reverberation die away uniformly in every direction.

*Rear Wall Construction.*—In the past, rear wall construction has often led to serious acoustical deficiencies in the theater. Unbroken walls have given rise to reflections into the audience with sufficient magnitude and time delay to be audible as echoes. Concave rear wall construction with consequent focusing of the reflected sound also has adversely affected sound quality. In contrast, convex surfaces provide the highest degree of sound dispersion.

The individual shaping may take different forms but should always diffuse the sound. Otherwise the sound reproduction will lack presence; that is, the voices of the actors will appear to come from a source other than the screen, and the illusion of reality, so important to the proper presentation of sound motion pictures, will be lost. A modified convex-type rear wall can be utilized to advantage in order to conserve seating area and at the same time to eliminate the focal difficulties inherent with concave rear wall design. Definite breaks in the contours which would have any tendency to form pockets and produce resonant cavities should be strictly avoided in the rear and side walls.

*Illustrations of Bad Acoustical Designs.*—A typical example of a theater with faulty acoustics is shown in Fig. 4. The auditorium is rectangular in shape with flat parallel side walls, a flat rear wall, and a relatively unbroken ceiling. These walls contribute to multiple echoes and a very bad overall acoustical condition. The intelligibility of the dialog is low.

Fig. 5 illustrates a side wall section constructed so as to focus the sound into the seating area. The concave wall surface adjacent to the stage focuses the reflected sound into the center section of the seating area, reducing screen presence and intelligibility. (This wall section is also shown in Fig. 7, viewed from the rear of the auditorium.)

By constructing the front portion of the side wall in a convex



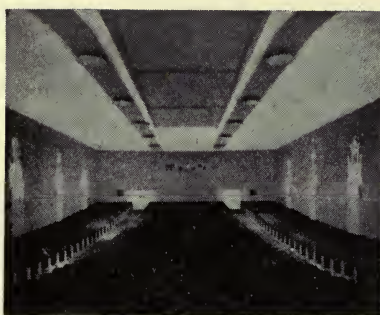


FIG. 4



FIG. 5



FIG. 6



FIG. 7



FIG. 8



FIG. 9

FIGS. 4-9. Illustrations showing features in theater design, with regard to acoustic properties.

shape as illustrated in Fig. 6, a properly diffusing surface is provided and the acoustic defects are avoided. The shape of the wall in Fig. 6 may be seen by noting the junction of the wall and the ceiling.

Another example is shown in Fig. 7, where the ceiling is also flat



and unbroken. In this case it was necessary to tilt the high-frequency horn well down into the audience to eliminate reflections from the ceiling. This decreased reflection effect provided a decided difference in quality between the front and back seating sections.

A recent trend in rear wall construction is shown in Figs. 8 and 9. When designed it was felt that such a tilting of the rear wall would reinforce the sound in the back portion of the seating area, giving a more uniform loudness level throughout the auditorium. Tests have indicated that these constructions are undesirable as this type of rear wall tends to concentrate low-frequency sound in rear audience areas and contributes to poor sound quality.

As a result of these experiences, such designs are considered impracticable, and it is recommended that the rear wall generally be



FIG. 10A

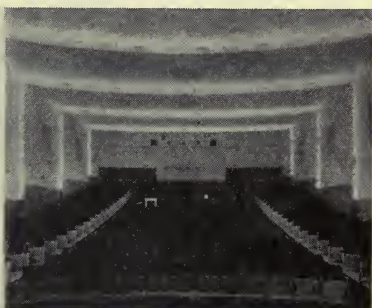


FIG. 10B

FIGS. 10A and B. Illustrating factors in theater design involved in acoustic response.

vertical and of such shape as to diffuse the reflected sound and to deliver it back into the audience in random directions. The rear wall must always be considered in conjunction with, and never separately from, the side wall, ceiling, and floor designs.

*Application of Good Design Principles.*—A practical example of the application of these design principles resulting in a theater with exceptionally good acoustics is illustrated in Figs. 10A and B. A shows the rear wall and ceiling construction as viewed from the side of the auditorium. B is a view from the stage. Fig. 10C shows in detail the vertical and horizontal cross-sections of the auditorium and the three different rear wall cross-sections.

This particular auditorium has been constructed on one of the studio lots and seats approximately 700 persons. However, in a

commercial application the rows would be closer together, so this theater may be considered to have a seating capacity of about 1000.

Although the principles of good design are fulfilled, certain features depart from the ideal given in Fig. 2. Fortunately, such deviations may be made without serious penalty. The side walls, while of straight sections, have been broken up to give a series of differently sloped small reflecting surfaces with the direction of reflection well into the side of the seating area. The same construction has been used on the ceiling. The rear wall surfaces consist of flat areas but the overall contour is convex, and the walls are sectioned in irregular sizes and at different angles so that each section contributes only a small reflection in any particular direction. It should be noted that all sections of the rear wall are vertical and do not tilt toward the seating area.

*Backstage Acoustical Treatment.*—In the reproduction of sound in the theater one of the most critical acoustical requirements is adequate backstage draping. In the design of the loud speaker and its associated unit every effort is made to minimize the amount of sound radiated from the back of the loud speaker. However, a certain amount of "leakage" radiation takes place and must be adequately absorbed. It is realized that efforts along this line have been made by various architects, but in general the absorption provided has not been sufficient.

Although the rear wall of the stage is often covered with rock-wool blankets, this material, when applied directly to a brick wall or other hard surface, has been inadequate. In other cases the absorption material has been set out from the wall on furring strips with the absorption material applied to wire mesh stretched across the strips to increase the low-frequency absorption properties. This is far more effective than the former method but still does not reduce the backstage reverberation time to the necessary negligible amount.

It has been observed that in a large number of cases this treatment is finished with a white surface, and for proper picture projection it is suggested that a black covering be used instead to avoid light reflections back to the screen.

Considering the type of backstage absorption treatment normally provided it has been necessary for the theater owners completely to cover the back of the screen with ozite, with the exception of the space occupied by the loud speakers.

Suitably located drapes around and above the loud speaker provide

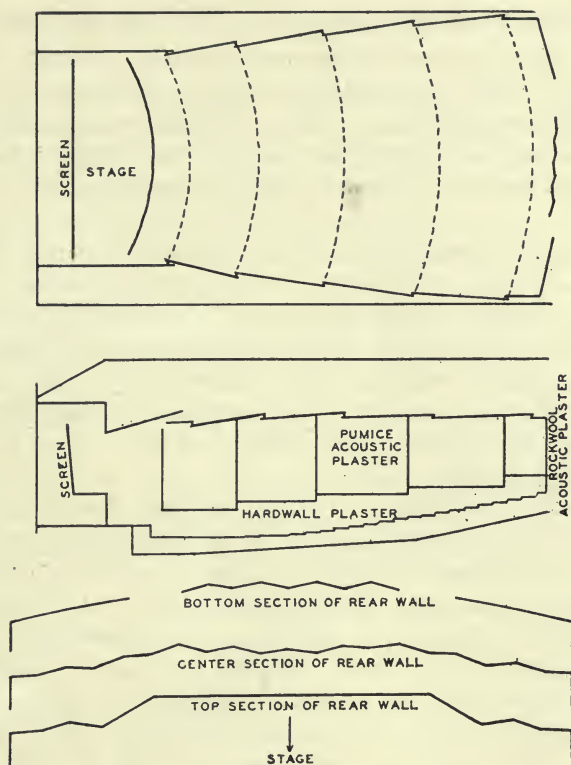


FIG. 10C. Cross-section, plan, and elevation of theater shown in Figs. 10(A) and (B).

an efficient means of absorbing undesirable backstage sound reflections. However, this type of treatment is an additional expense for the exhibitor and some form of speaker draping and screen masking should be combined in the initial design.

In the design of the stage of the auditorium, two factors should be borne in mind. First, for proper viewing and listening conditions the first row of seats should be at least 20 feet from the screen, where the screen is not more than 16 feet in width. For wider screens the first row of seats should be back an additional 15 inches for each foot of screen width over 16 feet. Second, the stage floor should be shaped to give an unobstructed view from the front seats, and the stage area should be covered with a rug or other sound-absorbing material to eliminate reflections directly from the loud speaker into the seating area.



## ABSORPTION CHARACTERISTICS OF ACOUSTICAL MATERIALS

The absorption characteristics of commercial acoustic materials vary widely. Some materials also show a pronounced absorption peak in their characteristics. These materials, while highly efficient for certain purposes (absorption of typewriter clicks, for instance) may be detrimental in a theater as their use produces a non-uniform response.

The materials selected should show a smooth absorption characteristic and adequate absorptivity at the low frequencies. For this reason care should be taken in selecting the material to be used in an auditorium in order that the desired overall effect be secured.

Modern acoustic materials are of such varied design and construction that it is possible for the architect to apply the proper sound-absorbing material and at the same time produce almost any artistic effect desired.

*Low-Frequency Absorption.*—Due to the fact that many acoustic materials are deficient in absorption at the low frequencies, it is often necessary to use these materials in a particular way to effect sufficient low-frequency absorption in the auditorium. To obtain this absorption at the extreme low frequencies the diaphragm action of the walls should be utilized. This action may be explained as follows: Where a wall is not rigidly supported, as in the case of a furred-out wall, it will act as a diaphragm and vibrate at certain frequencies, depending upon the dimension of the wall, the mass per unit surface, and the manner of wall support. This diaphragm action may either reinforce or absorb the sound near the particular frequency at which the wall resonates. If the wall has little internal resistance it will continue to vibrate after the original sound has died down and will re-radiate energy into the room, reinforcing the original sound.

In contrast to this, if the material has high internal resistance to vibration (as do masonite, celotex, and similar acoustic materials) the vibrations will die down faster than the reverberation time in the room and no "hang-over" effect takes place. To avoid a boomy house (which has excessive response in the region from 60 to 300 cycles) it is often advisable to make use of this diaphragm action to absorb these low registers.

In the practical application of such design, the furred-out walls should be made into different sized sections by irregular bracing of the wall itself. Such construction provides wall sections of different



dimensions which absorb the low frequencies through a wider band and avoid dips or peaks in the response characteristics.

*Non-Symmetrical Absorption Areas.*<sup>8</sup>—The most recent design considerations have proved the efficacy of using completely non-symmetrical small areas of absorption materials as contrasted with the earlier use of large treated surfaces. This non-symmetrical arrangement tends to maintain the long indirect path reflections and reduce the formation of surface patterns resulting in unsatisfactory sound conditions.

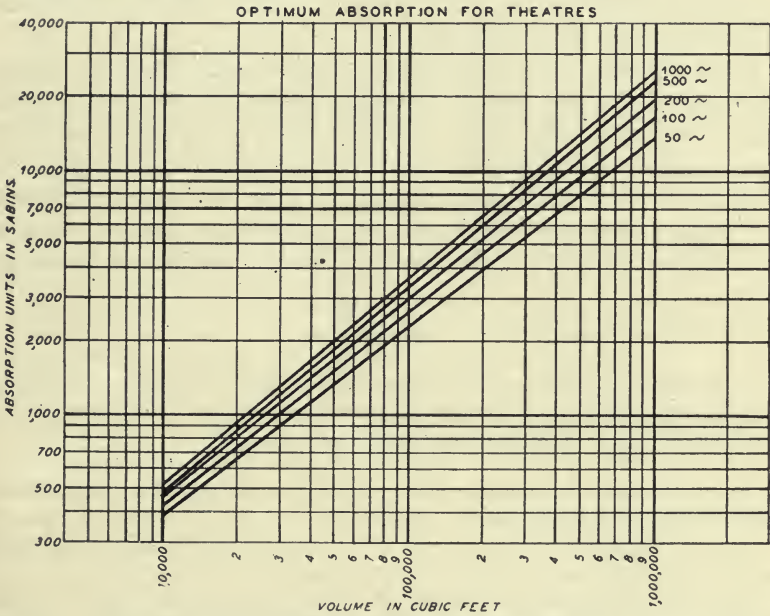


FIG. 11. Optimum amounts of sound absorption material for motion picture theaters.

The amount of sound absorption material necessary in theaters of various sizes is given in Fig. 11. This chart is useful for design purposes.

AUDITORIUM NOISE LEVEL

A theater, to have good acoustics, should have its walls insulated against the transmission of outside noise into the auditorium.<sup>9</sup> The transmission of sound is of two kinds: (1) air borne, and (2) structural.

Small openings around doors, windows, through port-holes, etc.,

transmit sound readily. For this reason all the joists between walls, doors, and windows which lead outside should be made as tight as possible. Transmission of sound through the building structure (such as the noise from vibrating machinery) can be minimized by using double-wall and double-floor construction, where required, and by separating all vibrating machinery from their supporting structure with vibration isolating materials such as cork or rubber. Massive walls are not always necessary to obtain sufficient sound insulation. A double wall of fairly light construction will give good sound insulation provided the two walls are not closely coupled mechanically by nails or rigid close members.

A large part of the transmitted noise often comes from the projection room. For this reason, as much fireproof acoustic material as possible should be placed on the inside walls and ceiling of the room. Since much of the projection room noise is radiated through open portholes or portholes with glass windows, these too should be treated.

It is also recommended that the air-conditioning system be operated at a low noise level, by employing a large-volume, slow-velocity system.

#### SUMMARY

In summarizing these theater acoustic recommendations reference is again made to Figs. 2 and 10, and the foregoing principles presented in outline form. The essential design features are:

(1) A minimum volume consistent with the required seating capacity and proper auditorium proportions.

(2) An auditorium width of from 50 to 70 per cent of the length and an auditorium ceiling height of not more than 40 per cent of the length.

(3) The use of non-parallel surfaces; in particular, the floor should not be parallel to any ceiling section or opposite side wall sections parallel.

(4) The use of convex rather than concave surfaces. In addition the wall and ceiling surfaces should otherwise be broken up so as to thoroughly diffuse the sound.

(5) Auditorium absorption characteristics to provide the same rate of sound decay in a vertical as in a horizontal direction from side to side or from back to front walls.

(6) Heavily upholstered seats and ozite-lined carpet in the aisles.

(7) Backstage treatment giving a negligible amount of reflected or re-radiated sound from the backstage into the auditorium.

(8) A heavily carpeted proscenium designed for good viewing conditions from the front seating section.

(9) Auditorium walls with sufficient sound insulation material to prevent extraneous noise entering the auditorium.

(10) The projection room acoustically treated with fireproof material and projection ports equipped with acoustic baffles.

(11) All equipment subject to vibration and hum such as arc generators, voltage regulators, lighting control equipment, *etc.*, acoustically isolated from the auditorium.

(12) Air-conditioning equipment of a high-volume, low air-velocity type with air ducts provided with acoustic baffles.

Long narrow auditoriums, high ceilings, excessively long and narrow balcony overhangs, concave focusing surfaces, and large unbroken reflecting areas should always be avoided as acoustical faults will always result from their use.

If these recommendations are followed, the resulting auditorium will give sound (as reproduced on a modern two-way equipment) with high intelligibility, warm, natural screen presence, good balance between high and low frequencies, uniform loudness level throughout the auditorium and the proper relative balance between high-level music passages and low-level, intimate dialog scenes.

#### APPENDIX\*

*Acoustic Absorptivity.*—The acoustic absorptivity of a surface is equal to one minus the reflectivity of that surface.

*Acoustic Reflectivity.*—The acoustic reflectivity of a surface which is not an original source, is the ratio of the rate of flow of sound energy reflected from the surface, on the side of incidence, to the incident rate of flow.

*Diffuse Sound.*—Sound is said to be in a perfectly diffuse state when, in the region considered, the energy density, averaged over portions of the region large compared to the wavelength, is uniform and when all directions of energy flux at all parts of the region are equally probable.

*Echo.*—An echo is a wave which has been reflected or otherwise returned with sufficient magnitude and delay to be perceived in some manner as a wave distinct from that directly transmitted.

*Echo, Flutter.*—A flutter echo is a rapid succession of reflected pulses resulting from a single initial pulse. If the flutter echo is periodic and if the frequency is in the audible range it is called a musical echo.

*Echo, Multiple.*—A multiple echo is a succession of separately distinguishable echoes from a single source.

*Mean Free Path.*—The mean free path for sound waves in an enclosure is the average distance sound travels in the enclosure between successive reflections.

*Rate of Decay.*—The rate of decay of sound energy density is the time rate at which the sound energy density is decreasing at a given point and at a given time. The practical unit is the decibel per second.

*Reverberation.*—Reverberation is the persistence of sound, due to repeated reflections.

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\* From "Acoustic Terminology," American Tentative Standard, Bull. Z24.1, 1936, *American Standards Association*.

*Reverberation Time.*—The reverberation time for a given frequency is the time required for the average sound energy density, initially in a steady state, to decrease, after the source is stopped, to one-millionth of its initial value. The unit is the second. Thus the time required for a sound to decay 60 db is the reverberation time.

*Sabins.*—The sabin is a unit of equivalent absorption and is equal to the equivalent absorption of one square-foot of a surface of unit absorptivity, *i. e.*, of one square-foot of surface which absorbs all incident sound energy.

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## AN OUTLINE OF THE WORK OF THE ACADEMY RESEARCH COUNCIL SUB-COMMITTEE ON ACOUSTICAL CHARACTERISTICS\*

JACK DURST\*\*

*Summary.*—This report includes a brief outline of the reasons for the formation of this Sub-Committee, the problems under consideration, and the manner of approaching a solution of these problems.

*In addition, tests and acoustical measurements as previously made are described and certain conclusions drawn.*

This report of the Academy Research Council's Sub-Committee on Acoustical Characteristics is intended primarily as a progress report on the Sub-Committee's program and will include only such conclusions as seem justified at the present time.

However, a brief outline of the reasons for the formation of the Sub-Committee, the problems under consideration, and the manner of approaching a solution of these problems, will be of interest to the members of the Society as the results of the work will eventually be of major benefit to all those engaged in recording and reproducing sound motion pictures.

This Sub-Committee was formed as a result of the work of, and functions under, the Council's Committee on Theater Sound Standardization, and so our discussion will be preceded by a brief résumé of some phases of that Committee's work.

In the early days of sound recording and up to the advent of the commercial two-way loud speaker system, the greatest effort in sound motion pictures had been toward improvement in recording equipment and technic. At that time it was felt that this phase of sound motion pictures had advanced more rapidly than the complementary reproducing equipment and technic. After the two-way loud speaker systems had been installed in many theaters in the United States, a decided trend toward uniformity of reproduced sound was expected,

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\* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received Dec. 20, 1940. (The Society is not responsible for statements by authors.)

\*\* Chairman.

but as a result of several field inspection trips by members of the Research Council it was evident that instead of a tendency toward uniformity there was a divergence in quality from theater to theater as well as between the products of different producers in the same theater. This was due to differences in the electrical characteristics of reproducing equipment as adjusted in the theater, bad acoustical conditions, and differences in recording characteristics.

As a result of this trend the Theater Sound Standardization Committee was formed to study the problem and to work toward uniformity in sound reproduction. Realizing that both art and science have played a most important part in sound motion pictures, there was no thought of introducing a degree of uniformity approaching monotony or lack of the effect of creative effort in sound as reproduced in the theater. On the contrary, it was felt that this uniformity was necessary in order that the producers and the sound departments, fore-armed with a knowledge of the reproducing characteristic, could obtain the utmost in naturalness and showmanship. Nor was there any thought that this standardization program was one which would be completed in a short time, but a program originally intended to cover a period of years was undertaken.

As a first and most important step, the Research Council Standard Electrical Characteristics were established for a majority of two-way reproducing systems. To establish these Standard Electrical Characteristics, a great number of listening tests were conducted in many theaters in the Southern California area, on each type of equipment under consideration. Theaters were chosen which were considered to have "average" acoustical conditions in the sense that acoustical deficiencies were not obviously present as shown by previous experience in listening to all types of products reproduced at previews and regular showings.

The Research Council Theater Sound Test-Reel (*ASTR-2*), consisting of typical current product from the major studios was made up by the Theater Standardization Committee. By listening to this material in the various theaters, data upon which the Standard Electrical Characteristics were based were obtained and the characteristics eventually established.

In consideration of the manner in which these Standard Characteristics were obtained, through listening tests in a great number of acoustically good theaters, it was felt that the acoustical effect of any one auditorium was minimized as the electrical characteristics speci-

fied were set up on a basis which actually included the average effect of theater acoustics.

The Committee fully realizes the incompleteness of such a specification since sound pictures are reproduced also in theaters having poor acoustics. It was also recognized that the specification of an acoustical characteristic would eventually give the complete and most eminently satisfactory answer to this particular phase of the problem.

The Research Council felt that steps should be taken to investigate acoustical measurements and this Sub-Committee was appointed to consider this problem.

In the opinion of the Sub-Committee, the problem resolved itself into six distinct sub-problems:

- (1) The selection of satisfactory portable measuring equipment.
- (2) The establishment of a suitable sound source making acoustical measurements reproducible within satisfactory tolerances under the most severe acoustical conditions.
- (3) The establishment of suitable calibrating and measuring technic most applicable for these purposes.
- (4) The study of acoustical response characteristics of review rooms.
- (5) The determination of the efficacy of the equipment and the technic of its use by making an extended series of measurements to gather data on acoustical response conditions in a number of average theaters.
- (6) The correlation of listening tests and acoustic measurements in theaters and review rooms.

It is readily apparent that the response characteristic of review rooms and theaters must be made to correspond before the studio personnel can definitely know, by listening in their projection room, how their product will sound in the field. In consequence, this correlation between review room and theater is an important and vital step in the standardization program of the Research Council.

It is definitely to the interest of this Committee in viewing the overall picture to recommend a technic which will be most practicable in the field. The considerations along these lines are quite varied but it is our aim to recommend a method and procedure which will, by virtue of its economy, be an asset to its users. It was obvious from the start that little progress could be made until such an equipment and such a method of measurement which would give reproducible results were available.

Columbia Pictures Corporation kindly made available to the Sub-Committee one of their studio review rooms for making preliminary tests and measurements. The curves in Fig. 1 show the results of

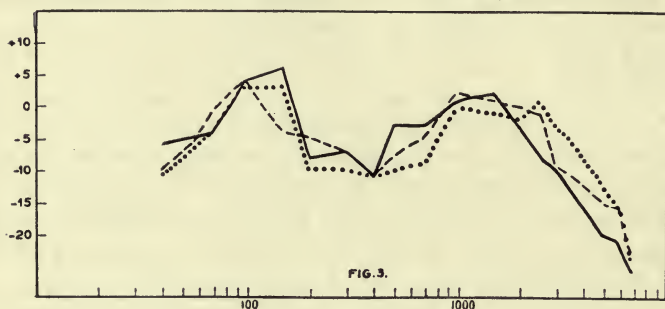
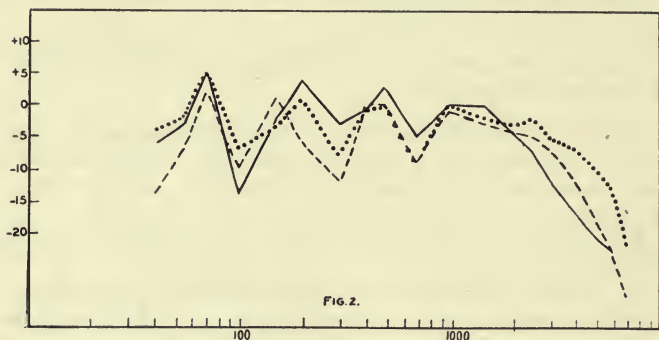
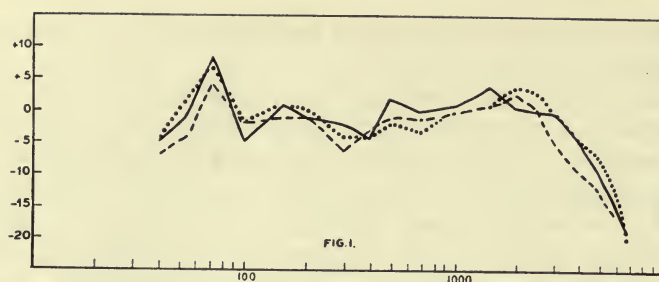


FIG. 1. Average.  
 FIG. 2. Position 1.  
 FIG. 3. Position 2.  
 (ERPI ———, RCA - - - - , GR .....)

our initial efforts. These are the averages of measurements shown in Figs. 2, 3, 4, and 5 for selected individual locations. As indicated, three types of measuring equipment were employed: namely, the ERPI high-speed level recorder with a pressure type microphone, the RCA sound level meter using a velocity type microphone, and a General Radio noise-meter with a crystal microphone. A warble



film having an 8-cycle rate and a  $\pm 5$  per cent modulation factor was used as a sound-source.

While the variation in the results was definitely discouraging, work was carried on exploring the many possibilities of different sound-sources such as random emission noise, multitone, and various types of warble tones.

By employing the same calibrating equipment and an identical sound-source, calibrations of all the measuring equipments were made by this group, at all times employing the same measurement technic. ERPI made available their equipment for these calibrations. Check tests made under the same acoustical environment showed a very gratifying improvement. The deviations which previously approached 10 db were reduced to the order of 2 db.

The Altec Service Corporation conducted a very extensive study of warble tones and published their findings in the February, 1940, issue of the JOURNAL. With their coöperation a new warble film was recorded having the characteristics of warble rate and modulation which their research disclosed as being most suitable to this type of measurement.

The upper curves of Fig. 6 show the results of later measurements made with improved sound-sources and recalibrated equipments. They represent the averages of the curves of Figs. 7, 8, 9, and 10. For comparison purposes, Fig. 1 has been reproduced on the same chart.

It is interesting to note the consistency of the results as well as the general smoothing out of the measured characteristics. This latter effect is due largely to the changes made in the sound-source, and the resulting smoother curve more nearly corresponds with what the ear hears. From the standpoint of accomplishment it is of interest to make direct comparisons not only of the averages but also of the individual positions; for example, it will be observed that the extreme "raggedness" originally measured in position 1 has now become a relatively smooth characteristic. The original measurements made in position 1 could not be correlated with listening tests. Yet these later measurements were made with the same measuring equipments except that they had been accurately calibrated and the rate as well as the percentage of modulation of the warble film had been changed. Repeated tests made at substantial intervals proved that these measurements could be readily duplicated within practical tolerances. Furthermore, these measurements permitted a satisfactory

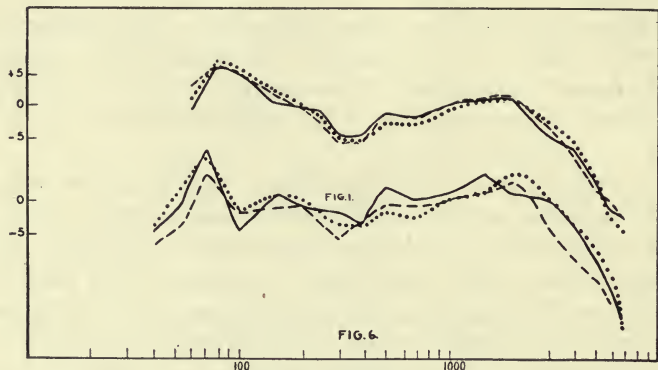
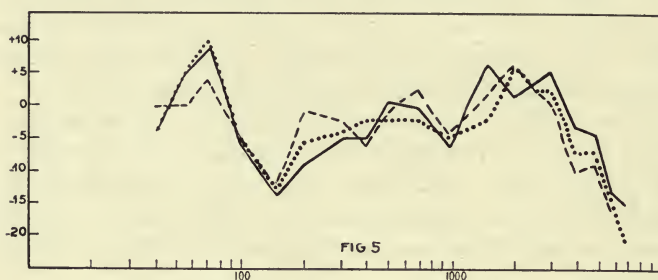
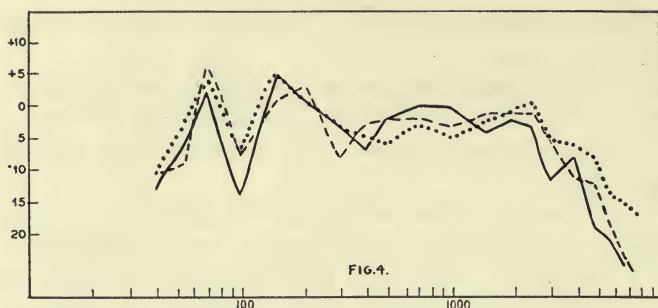


FIG. 4. Position 3.

FIG. 5. Position 4.

FIG. 6. Average.

(ERPI ———, RCA - - - - , GR .....)

degree of correlation with listening tests. Direct comparisons were made by listening to both the warble tone and the Academy Theater Test-Reel in the various positions used for measurements, and it was agreed that the two tests gave positive indication that we had measured the differences which were detectable by ear.

For further verification of this, a test was made in a medium-size theater with another group of observers. In this case, the acoustical response characteristic, as shown Fig. 11, was set without the knowl-

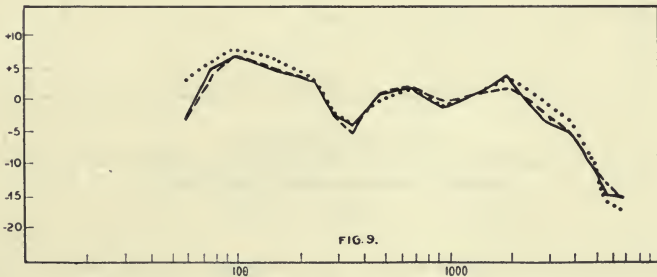
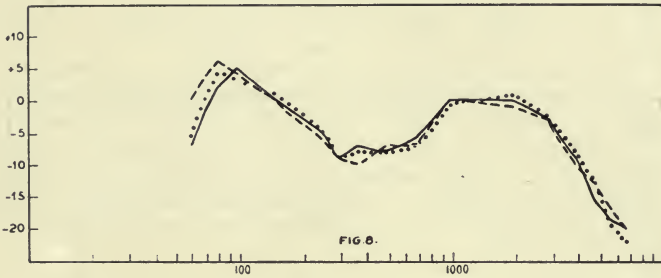
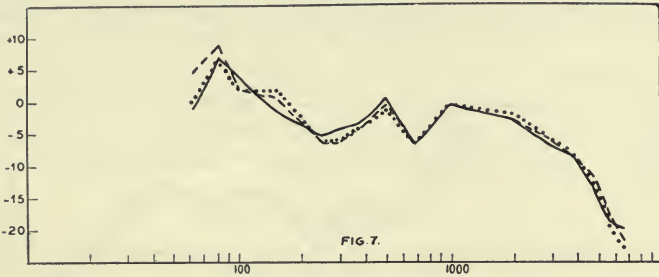


FIG. 7. Position 1.

FIG. 8. Position 2.

FIG. 9. Position 3.

(ERPI —, RCA ---, GR .....)

edge of any of the observers. The observers were permitted to listen only to the Academy Theater Test-Reel and to indicate what they heard in terms of relative frequency response. Without exception, it was agreed that there was an excess of energy at 150 cycles, a lack of energy from 500 to 700 cycles, and that the high end was

held flat to approximately 4000 cycles and sharply attenuated above this frequency.

With this evidence it was felt that our present measuring procedure not only lends itself to correlation with listening but also provides a definite means of diagnosis of improperly adjusted characteristics.

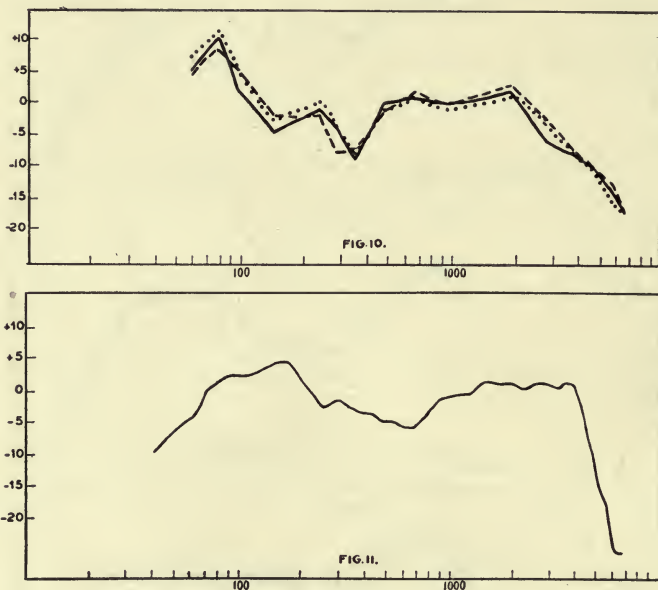


FIG. 10. Position 4.  
FIG. 11. Undesirable acoustic characteristic confirmed by listening tests (average of five positions).  
(ERPI ———, RCA - - - -, GR .....)

The Committee has solicited the coöperation of the two major theater service organizations in the interests of obtaining acoustical response characteristics in several hundred theaters. The measurement procedure is given in an Appendix.

With the data obtained from these tests and the assistance of the Theater Standardization Committee, it is believed that an optimum acoustical characteristic may be established. It must be borne in mind, however, that listening tests must be the final and basic criterion for the determination of theater system adjustments. The entire program of this Sub-Committee has been predicated on the



theory that the development of a scientific tool as an adjunct to listening will permit better standardization of acoustical response characteristics throughout the industry.

We wish to take this opportunity to acknowledge the helpful cooperation of Altec Service Corporation, Columbia Studio, Electrical Research Products, Inc., General Radio Company, International Projector Corporation, Lansing Manufacturing Company, Paramount Studio, RCA Manufacturing Company, Samuel Goldwyn Studio, and Warner Brothers Studio, for helpful suggestions, the use of studio facilities, testing equipment, and sound-sources.

### APPENDIX

#### PROCEDURE FOR ACOUSTICAL RESPONSE MEASUREMENTS IN SINGLE-FLOOR THEATER AUDITORIUMS

*(Having Modern Two-Way Speaker Systems)*

(1) For these response measurements 6 positions are chosen: 5 positions in the auditorium and 1 stage position, as indicated on Fig. 12. If the house is symmetrical, positions should be located in the same half of the house. No position should be closer than 10 feet to any reflecting surface such as a wall or pillar. In making these response measurements use the microphone mounted on a tripod and keep all observers at least 10 feet away from the microphone during the run.

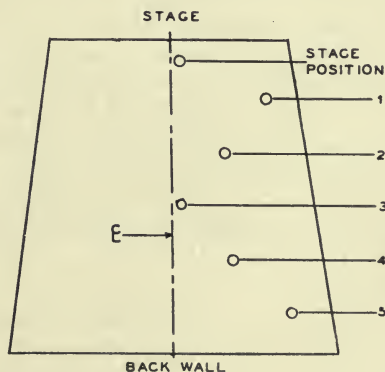


FIG. 12. Showing positions for response measurements.

(2) For the stage position, locate the microphone about 10 feet in front of the screen and about 18 inches from the theater centerline. The microphone should be approximately at the height of the top of the low-frequency horn or baffle. The Academy Research Council Warble Film (No. 6490) is projected at normal fader setting for the theater and the readings recorded on the data sheet under



"Stage Position" together with the height of the microphone and its distance from the screen.

(3) At position 1 (Fig. 12) locate the microphone on a seat at the average ear height of a seated observer. Record the row and seat number in the "Position 1" column of the data sheet (Fig. 13). Using the same machine and fader setting, project the warble film as before, and record the sound level readings in the

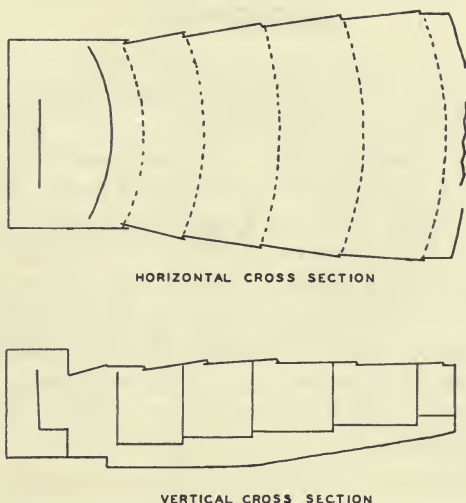


FIG. 14. Cross-section required for data sheet.

"Position 1" column of the data sheet. Repeat this procedure in positions 2, 3, 4, and 5. Record the row and seat number of each position and the sound level readings in the appropriate column of the data sheet.

(4) Record on the data sheet the information requested to aid in evaluating the acoustical measurements. In the space provided sketch the vertical and horizontal cross-sections of the theaters as illustrated in Fig. 14.

## TWENTY-FOUR YEARS OF SERVICE IN THE CAUSE OF BETTER PROJECTION\*

E. A. WILLIFORD\*\*

In July, 1916, a group of 26 men, farseeing and prominent engineers, who were then pioneering the problems of a growing industry, got together in Washington and organized what they called the Society of Motion Picture Engineers. Mr. C. Francis Jenkins, engineer and inventor, residing in Washington, acted as temporary chairman. At this meeting, which may be regarded as an organization meeting, a Constitution and By-Laws were drawn up and adopted, in which the aims of the Society were set forth as "the advancement in the theory and practice of motion picture engineering and the allied arts and sciences, the standardization of the mechanisms and practices employed therein, and the maintenance of a high professional standing among its members."

Immediately the new group began to hold meetings to which were attracted quite a number of persons interested in the then relatively young art of motion picture engineering.

Mr. Jenkins, after the completion of the organization, was elected President of the Society, with Mr. D. G. Bell of Chicago, and Mr. E. M. Porter of New York as Vice-Presidents, and with Mr. E. K. Gillette of New York and Mr. Paul Brockett of Washington as Secretary and Treasurer, respectively. Other notable persons on the membership list at that time were Messrs. Carl Akeley, Max Mayer, and Herman Kellner.

By the time of the first formal meeting, which was held in October, 1916, the membership had grown considerably, numbering about 40 persons. Of that small group, we still have with us, as members of the Society, Messrs. A. S. Victor, F. H. Richardson, and W. C. Kunzmann. All the other members of that time have since either died or otherwise dropped out of our membership.

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\* Reprinted from the *Modern Theater* Section of *Box Office*, Oct. 12, 1940, p. 56.

\*\* President, Society of Motion Picture Engineers, 1939-40.



The technical activities of the new Society gained a good start at the first formal meeting in 1916 through the formation of the following committees:

Committee on Cameras and Perforations  
Committee on Picture Theater Equipment  
Committee on Motion Picture Electrical Devices  
Committee on Optics

The dues in those days were quite interesting. Charter memberships in the Society were divided as follows:

Pioneer Member	\$250.00
Honorary Member	100.00
Active Member	25.00
Associate Member	25.00

Regular memberships in the Society (that is, not Charter memberships) were established in the following grades:

Active Membership	Entrance Fee	\$25.00
	Annual Dues	10.00
Associate Membership	Entrance Fee	25.00
	Annual Dues	5.00

Those responsible for the organization of the Society wisely made its aims and purposes rather broad, providing for the development of its activities in many and diverse fields of an industry destined to grow to enormous size and to cover in its activities a wide range of scientific and artistic endeavor. There is little doubt, however, that the one thing uppermost in the minds of the men who formed this Society, the one thing they considered of prime importance, and of immediate necessity for the welfare of the industry, was the standardization of materials, mechanisms, and practices. As a matter of fact, at the first meeting, although only one paper was presented, that by H. D. Hubbard of the U. S. Bureau of Standards, the subject of that paper consisted entirely of a discussion of standardization, and the necessity of standardization in the motion picture industry.

At the second meeting, at which time Mr. Jenkins was chosen President, the President's address was a plea for standardization, and two or three papers on the program dealt directly with the standardization of motion picture film and mechanism. Although no

formal "Standards Committee" had been formed, it was from this beginning that the present standardization activities of the Society have grown.

From the beginning, regular meetings of the Society were held in the spring and fall of each year. These meetings were more in the nature of conventions at which groups of papers were presented and discussed, similar to those the Society now holds semi-annually. It is interesting that the method of conducting conventions has not changed in all these twenty-four years; and it is also interesting to note that one of our present members, our Convention Vice-President, Mr. W. C. Kunzmann, was not only present at the first formal meeting of the Society but has attended every Convention that the Society has ever held.

The papers presented at each meeting were collected into groups and published in two volumes a year. These volumes were known as the "Transactions of the Society of Motion Picture Engineers." Some of the early issues were rather thin, but each year, up to and including 1929, showed a steady growth. The first *Transactions* contained only one paper—the address by Mr. Jenkins. The second *Transactions* contained three papers. The *Transactions* of 1928 embodied 1222 pages of printed material.

In the meantime, the Society had steadily grown, although at first rather slowly. In 1928 the total membership was 320, with 185 Actives and 135 Associates. It will be noted that in these days the Active membership exceeded the Associate.

In 1929, sound came into the picture, and, with the addition of electrical engineers, radio engineers, and other kinds of engineers to the industry, the membership of the Society took a big jump. In 1931, the membership had leaped to 765, almost equally divided between the Active and Associate grades.

About this time it became recognized that great loss of value and great inconvenience resulted from concentrating the publication of papers presented at meetings into two volumes of the *Transactions* a year. It had become increasingly important for engineers of the industry to receive their technical information promptly and regularly. For that reason, in 1930, through the insistent efforts of Dr. Loyd A. Jones and Mr. John I. Crabtree, who was then President, the Society was fortunate in being able to enlist the financial assistance of various companies of the industry for the purpose of expanding the technical scope of the Society and putting the *Transactions*

on a monthly basis. A fairly large group of producing companies and equipment manufacturers subsidized the Society to the extent of almost \$10,000. The name *Transactions* was discontinued, and in January, 1930, the first monthly JOURNAL was issued.

Up to this time, engineers had been regarded by many motion picture executives as being very much apart from the industry; and, in fact, at a banquet tendered to the Society, meeting in Hollywood in 1928, by the Academy of Motion Pictures Arts and Sciences, one of the outstanding executives of a producing company admitted that prior to that occasion he had not even heard of the Society of Motion Picture Engineers. The motion picture technician had at last been given the spotlight, and, since that time, his importance and value to the motion picture industry have been more and more deeply realized. It can not be disputed that the success of the motion picture industry, as we know it today, lies to an enormous extent in the hands of the technicians.

The Society of Motion Picture Engineers contributed in no small way to the successful accomplishment of the transition from the silent picture to the sound picture, and the *Transactions* contained the first published accounts of the first systems of recording and reproducing sound.

During the first year of the issuance of the JOURNAL (1930) Dr. L. A. Jones acted as temporary Editor. The clerical and administrative work of the Society up to this time (1930) had been attended to by officers acting without remuneration, in their homes or in the offices of their firms. The steady growth of the Society and its success in coordinating the technical activities of the industry can in very large measure be attributed to the sacrifices made and the inconveniences endured by those officers conducting their Society work under what were at best inadequate facilities.

Just as prior to 1930 it had long been the dream of the governors to put the *Transactions* on a monthly basis, so, with the growth of the industry and of the Society, and with the undue burdens placed upon the men who fostered his growth, the Board began to give thought to the establishment of permanent headquarters for the Society, and the employment of a man for the purpose of relieving the officers of much of these burdens.

Accordingly, permanent headquarters of the Society were established at 33 W. 42nd Street, New York, N. Y., with Mr. Sylvan Harris as Editor of the JOURNAL and Office Manager, in which ca-



capacity he has been acting for the past ten years. In 1934 the office was moved to the Hotel Pennsylvania.

The scope of the Society's technical activities grew very rapidly; the number of technical committees was increased to embrace all phases of sound engineering, acoustics, and many of the new arts brought into the motion picture field. Additional technical committees were established to cover phases of the industry that had heretofore been neglected, such as projection practice. The list of committees, as constituted today, presents a most imposing picture of the breadth of the Society's technical activities. The technical committees at present functioning are:

- Color
- Exchange Practice
- Laboratory Practice
- Non-Theatrical Equipment
- Preservation of Film
- Progress
- Sound
- Standards
- Studio Lighting
- Television
- Theater Engineering (including projection practice and theater design)

In addition, the Society holds representation in the American Documentation Institute, the Sectional Committee on Motion Pictures of the American Standards Association, the Sectional Committee on Photography of the American Standards Association, and the Inter-Society Color Council.

Attending the economic fiasco in 1929, the membership suffered a severe loss, dropping from a total of 765 to 560. Broad revisions of the Society's membership policies and alterations of the membership dues were then made so that it would be more easily possible for members of the industry to become members of the Society. A third grade of membership was created, known as Fellow membership, and the dues of the other grades were revised to the following figures:

Fellow.....	\$20.00
Active.....	15.00
Associate.....	10.00

Admission fees were eliminated. With these changes, and with the gradual reconciliation of the people to the new economic situation,



and with the help of a vigorous membership campaign, under the guidance of Mr. E. R. Geib, the membership again began to increase. Subsequent revision of the dues to the present figures in force, given below, added considerably to the growth, and despite unsettled world conditions during the past several years, there has been a steady increase of membership since the low point of 1933 up to the present. At this time the Society's membership is the largest it has ever been, totaling almost 1400 members. This membership includes all sorts of persons engaged in the motion picture industry and its allied arts and sciences, and many others who make motion pictures their avocation.

It is interesting to note these various groups of persons who are members of the Society:

- Laboratory technicians
- Photographic chemists
- Cinematographers
- Projectionists
- Equipment manufacturers
- Equipment designers
- Producers
- Directors
- Theater managers
- Sound recordists
- Illuminating engineers
- Exhibitors
- Opticians
- Exchange managers
- Film editors
- Physicists
- Acoustical engineers
- Amateur cinematographers

There are technical experts of all the important research laboratories and other engineering organizations throughout the entire world, exclusive of the manufacturing, producing, and exhibiting branch of the industry, and the roll of members includes the names of many distinguished scientists and engineers, in addition to the honorary members of the Society. There is only one honorary member of the Society at the present time, namely, Mr. Thomas Armat of Washington, D. C., who was one of the pioneers of the motion picture. Others who have been honorary members of the Society but whose names, at their deaths, have been placed upon the Society's Honor Roll, are as follows:

Louis Aimé Augustin Le Prince  
William Friese-Greene  
Thomas Alva Edison  
George Eastman  
Frederic Eugene Ives  
Jeane Acme Le Roy  
C. Francis Jenkins  
Eugene Augustin Lauste  
William Kennedy Laurie Dickson

Probably one of the most important activities of the Society is its standardization program. The standards that have been established by the Society include dimensional specifications of film and perforations and sprockets, the relation between emulsion and sound-track positions in scanned areas, reels, projection lenses, splices, screen sizes, projection room lay-out, sensitometry, photographic density, screen brightness, and motion picture nomenclature. Many of these standards have passed from the status of motion picture industry standards to American national standards; and some have actually become international in scope, having been approved by the International Standards Association just prior to the present war in Europe. The Society's interest includes all sizes of motion picture film and equipment, in addition to the customary 35-mm professional size.

As an important technical contribution to the industry, several years ago the Society, through the Projection Practice Committee, designed and made available to the motion picture industry a sound test-film and a visual test-film, designed for the purpose of checking the operation of equipment in the motion picture theater. These films have since been used very extensively throughout the world and to quite a large extent by various departments of the United States Government. Many companies, and a number of governmental departments, have based their purchases of projection and sound reproducing equipment upon performances as checked by these SMPE test-films.

All the technical activities of the Society are presented, described, and discussed at the conventions of the Society, which are held twice a year. The sessions usually last four days and are attended by hundreds of members and their friends and relatives. At the semi-annual banquet, with a customary attendance of several hundred, each visitor, whether delegate or guest, carries away with him the memory of a great occasion. Technical papers, followed by discus-

sions of the papers by the members, demonstrations of newly developed apparatus and methods, open-forum discussions of the problems of the industry, and exhibitions of equipment are technical features of the conventions. These are supplemented by an interesting program of social and entertainment features.

The headquarters of the Society are located in New York, where members of the Society and their friends are always welcome. It is the seat of the editorial activities, and the avenue through which the various functions of the Society are administered. All members are welcome to visit the General Office at any time, and to take advantage of such privileges as it may be able to provide in the form of service to the members. The office is located on the mezzanine of the Hotel Pennsylvania, Seventh Avenue and 34th Street, New York, N. Y.

Local Sections of the Society have been established for the purpose of enabling the members in the three great motion picture centers of the United States to conduct and attend meetings in their own districts. The three sections are the Atlantic Coast Section, which meets regularly at New York or nearby; the Mid-West Section, which operates for the benefit of members residing in and about Chicago; and the Pacific Coast Section, which meets in Hollywood.

Membership in the Society is open to anyone interested in the motion picture art. The two grades of membership make it possible for anyone to participate in the Society, whether a novice at the art, or an eminent authority in any of the many fields of endeavor in the motion picture industry, whether interested in motion pictures as an avocation, or because of business or professional connections with the industry. The fees are low, having been reduced to the lowest level at which it is still possible for the Society to serve the industry effectively.

REQUIREMENTS AND FEES

Grade	Min. Age	Years of M. P. Work	Number of References	Annual Dues
Active	25	3	3 Fellows or Actives	\$15.00
Associate	18		1 Fellow or Active	7.50

The Society's office will gladly furnish, upon request, further information covering membership in the Society, and will be glad to extend its facilities to anyone in the motion picture industry, whether a member or not, in search of technical or other relevant information.



## LINE MICROPHONES\*

HARRY F. OLSON\*\*

*Summary.*—A line microphone is a microphone consisting of a large number of small tubes with the open ends, as pick-up points, equally spaced along a line and the other ends connected by means of a common junction to a transducer element for converting the sound vibrations which converge upon the junction into the corresponding electrical variations. Several types of line microphones with the useful directivity along the line axis are described as follows: a simple line, a line with progressive delay, and two lines with progressive delay and a pressure gradient element.

The directional characteristic of a microphone is an expression of the variation of behavior of the microphone with respect to direction. The solid angle over which sound is received without appreciable attenuation relative to the maximum response characterizes a directive sound-collecting system. The effective solid angle of the directional characteristic determines the ratio of direct to generally reflected or other undesirable sounds. The shape and magnitude of the solid angle of the directional characteristic determines the ratio of direct to generally reflected sound. One important requirement is a directional characteristic which is independent of the frequency. A system which does not possess this characteristic will introduce frequency discrimination in both the desired and undesired sounds.

The preferable directional characteristic of a microphone for a particular application will depend upon the pick-up problem. For example, the bidirectional velocity microphone has been found to be very useful for overcoming excessive reverberation, eliminating undesirable sounds, and as a tool for obtaining a "correct balance" of the received sound. The unidirectional microphone has been found to be particularly useful where the desired sounds originate in front of the microphone and the undesired sounds at the rear of the microphone. These microphones have demonstrated the usefulness of directional microphones in sound motion picture recording,

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\* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received September 30, 1940. (The Society is not responsible for statements by authors.)

\*\* RCA Manufacturing Co., Camden, N. J.



radio broadcast, phonograph recording, and sound reinforcing systems. It has been found that directional sound-collecting systems are more effective than nondirectional systems in problems connected with sound collection, such as balance and reverberation in music, long distance pick-up of speech, and feedback difficulties in sound reinforcing. In view of this demonstrated usefulness, further consideration has been given and efforts directed toward the development of other directional systems. It is the purpose of this paper to describe a number of directional microphones of the line type.

A line microphone is a microphone consisting of a large number of small tubes with the open ends, as pick-up points, equally spaced along a line, and the other ends connected by means of a common junction to a transducer element for converting the sound vibrations which converge upon the junction into the corresponding electrical variations. In the line systems to be considered the transducer will be a ribbon element located in a magnetic field and terminated in an acoustic resistance. Under these conditions the outputs of the pipes may be added vectorially. By suitable impedance terminations other transducer elements may be used to obtain the same type of operation, that is, so that the outputs may be added vectorially.

*Simple Line Microphone.*—The simple line microphone consists of a number of small pipes, with the open ends, as pick-up points, equally spaced on a line and the other ends joined at a common junction, the lengths of the pipes decreasing in equal steps (Fig. 1). A ribbon element, in a magnetic field, connected to the common junction and terminated in an acoustic resistance in the form of a long damped pipe, is used for transforming the acoustical vibrations at the ribbon into the corresponding electrical variations.

The pressure contribution by any element  $n$  at the common junction of the line may be expressed as

$$p_n = B_n e^{2\pi i f t} e^{2\pi i (x_n - x_n \cos \theta) / \lambda} \quad (1)$$

where  $f$  = Frequency, in cycles per second.

$t$  = Time, in seconds.

$x_n$  = Distance of the element  $n$  from the center of the line, in centimeters.

$\theta$  = Angle between the axis of the line and the incident sound.

$B_n$  = Amplitude of the pressure, in dynes per square-centimeter, due to the element  $n$ .

In the case of a uniform line with the strength a constant, the resultant when all the vectors are in phase is  $B_n l$  where  $l$  is the length of the line.

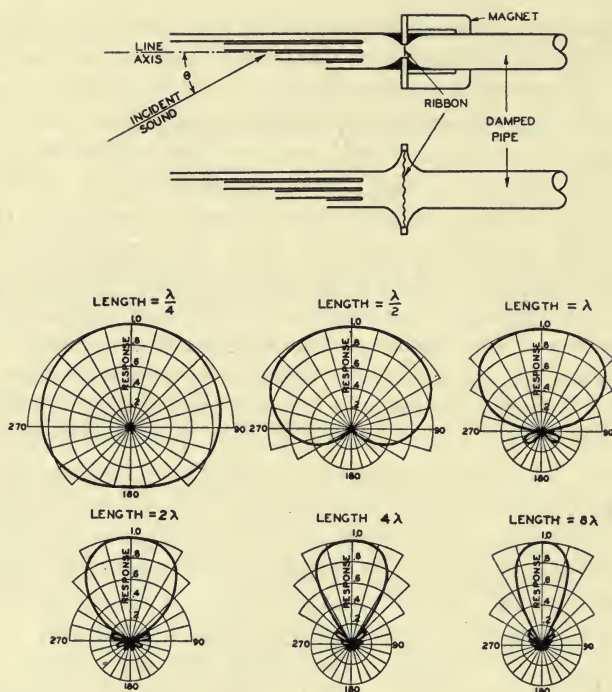


FIG. 1. Simple line microphone and the directional characteristics as a function of the length of the line and the wavelength.

The ratio  $R_\theta$  of the response for the angle  $\theta$  to the response for  $\theta = 0$  is

$$R_\theta = \frac{1}{B_n l} \left| \int_{-\frac{l}{2}}^{\frac{l}{2}} B_n e^{2\pi j [f t + (x - x \cos \theta) / \lambda]} dx \right| \quad (2)$$

The absolute value of the expression on the right hand of equation 2 is given by

$$R_\theta = \frac{1}{l} \left| \int_{-\frac{l}{2}}^{\frac{l}{2}} e^{2\pi j (x - x \cos \theta) / \lambda} dx \right| \quad (3)$$

$$R_\theta = \frac{\sin \frac{\pi}{\lambda} (l - l \cos \theta)}{\frac{\pi}{\lambda} (l - l \cos \theta)} \quad (4)$$

The directional characteristics of the simple line microphone for various ratios of length of the line to the wavelength are shown in Fig. 1. These characteristics are surfaces of revolution about the line as an axis.

*Line Microphone with Progressive Delay.*—Referring to Fig. 1, it will be seen that the length of the line must be of the order of several wavelengths to obtain a directional characteristic with a relatively small effective solid angle. Practically, the simple line type of microphone becomes quite long if high directivity is desired at the

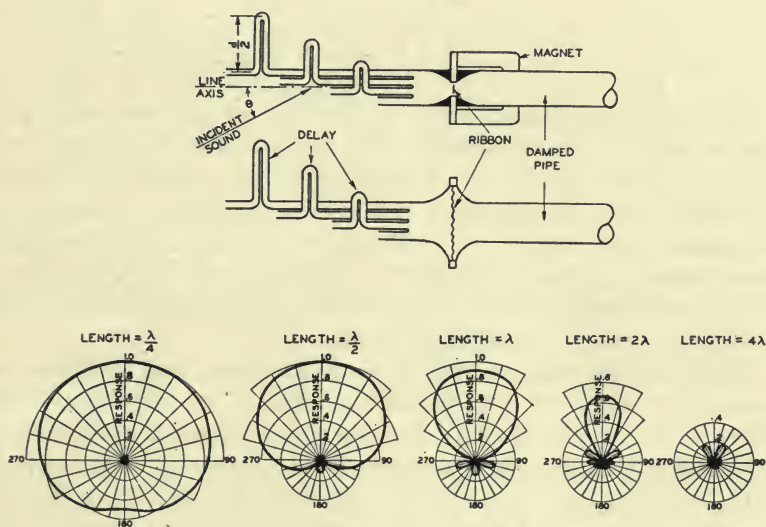


FIG. 2. Line microphone with progressive delay and the directional characteristics, for a time delay equal to one-quarter the length of the line, as a function of the length of the line and the wavelength.

lower part of the audible spectrum. However, it is possible, by introducing into the pipes a delay which becomes progressively greater with the length of the individual pipes, to effect an increase in directivity; that is, a decrease in the effective solid angle of pick-up over that obtained with the same length of simple line. As in the case of Fig. 1, the microphone of Fig. 2 consists of a number of small pipes with the open ends as pick-up points equally spaced along on a line and the other ends joined at a common junction, with the addition that there is inserted a delay which is proportional to the distance

from the end of the line or the pick-up point nearest to the common junction.

The ratio  $R_\theta$  of the response for the angle  $\theta$  to the response for  $\theta = 0$  is

$$R_\theta = \frac{1}{B_n l} \left| \int_{-\frac{l}{2}}^{\frac{l}{2}} B_n e^{2\pi j [ft + (x - x \cos \theta)/\lambda + d/\lambda]} dx \right| \quad (5)$$

where  $d$  is the path length of the delay introduced for the point farthest removed from the common junction.

$$R_\theta = \frac{\sin \frac{\pi}{\lambda} [l - l \cos \theta + d]}{\frac{\pi}{\lambda} [l - l \cos \theta + d]} \quad (6)$$

The directional characteristic of the line microphone, with progressive delay for various ratios of the length of the line to the wavelength, is shown in Fig. 2. A measure of the value of a line with progressive delay as compared to a simple line may be obtained by comparing Figs. 1 and 2. It will be seen that the same directional characteristic can be obtained with a line of shorter length by introducing appropriate delay. In the case of a delay comparable to the wavelength, loss in sensitivity occurs.

*Two-Line Microphone with Progressive Delay and a Pressure-Gradient Element.*—This microphone consists of two lines of the type shown in Fig. 2 arranged so that the ribbon element measures the difference in pressure generated in the two lines (Fig. 3). The centers of the two lines are separated by a distance  $D$ . In the line nearest the ribbon element, a bend of length  $D$  is inserted between the junction and the ribbon element.

To show the action of the pressure-gradient element, assume that the small pipes are removed and the two junctions, at  $J_1$  and  $J_2$ , Fig. 3, are used as the pick-up points. These two pick-up points are then separated by a distance  $D$ . The difference between the forces on the two sides of the ribbon, assuming the mass reactance of the ribbon system to be large compared to the resistance of the damped pipes, may be expressed as

$$F_M = A \cos (2\pi ft) \sin \left( \frac{\pi D \cos \theta}{\lambda} \right) \quad (7)$$

where  $A$  is a constant, including the pressure of the impinging sound-wave and dimensions of the microphone.



If  $D$  is small compared to the wavelength, equation 7 becomes

$$F_M = A \frac{\pi D}{\lambda} \cos (2\pi f t) \cos \theta \quad (8)$$

Equation 8 shows that the force available for driving the ribbon is proportional to the frequency and the cosine of the angle  $\theta$ .

Employing a mass-controlled ribbon of mass  $m_r$ , the velocity is given by

$$\dot{x} = \frac{A}{2\pi m_r} \left( \frac{\pi D}{c} \right) \sin (2\pi f t) \cos \theta \quad (9)$$

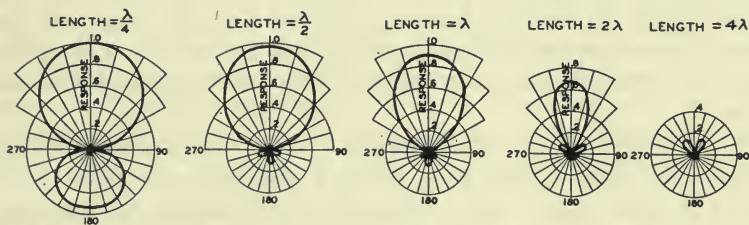
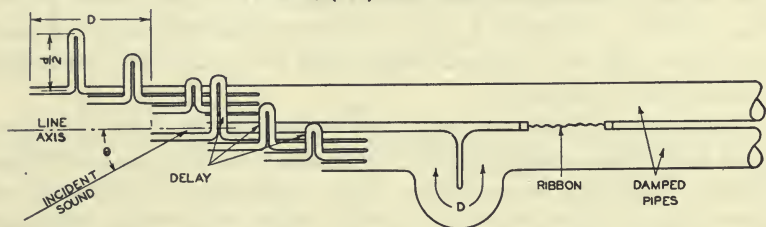


FIG. 3. Pressure gradient line microphone consisting of two lines with progressive delay and a pressure gradient element and the directional characteristics for a time delay equal to one-quarter the length of the line, as a function of the length of the line and the wavelength.

Where  $c$  is the velocity of sound, in centimeters per second. The velocity  $\dot{x}$  is independent of the frequency for a constant sound pressure, and as a consequence the ratio of the generated electromotive force to the pressure in the sound-wave will be independent of the frequency.

In the above discussion the junctions are assumed to be non-directional. The directional characteristics of the individual lines are given by equation 6. Therefore the expression for the directional characteristics of the combination of these lines with a pressure-gradient element is the product of equations 6 and 9. The directional characteristic is given by

$$R_{\theta} = \frac{\sin \frac{\pi}{\lambda} (l - l \cos \theta + d)}{\frac{\pi}{\lambda} (l - l \cos \theta + d)} \cos \theta \quad (10)$$

The directional characteristics of the microphone of Fig. 3, for various ratios of the length of the line to the wavelength for a delay of one-half the length of the line, combined with a pressure-gradient element, are shown by the graphs of Fig. 3. A measure of the improvement in directivity obtainable from a line with progressive delay and a pressure-gradient element may be obtained by comparing Figs. 1 and 3. Employing these expedients, approximately the same directivity may be obtained with a line of one-quarter the length necessary for a simple line.

*Conclusion.*—Directional microphones employing lines of various types have been described, the directional characteristics of which indicate considerable variation with frequency. Experience has shown that a directional characteristic which varies with frequency is undesirable because frequency discrimination is introduced in the direct sound for sources of sound removed from the axis. In addition, the response to reflected sound is a function of the frequency, and the reverberation characteristics of the received sound is thereby altered.

Experiments upon directional systems have indicated that a microphone with a small solid angle of pick-up would be extremely useful in certain applications such as in sound motion picture recording, in television pick-up, in symphony and stage pick-up, in sound broadcasting, and in sound reinforcing. The line type of microphone discussed in this paper appears to be the logical solution from the standpoint of size and portability. However, the directional characteristics must be independent of the frequency. This result<sup>1</sup> can be accomplished by employing a number of separate lines each covering a certain portion of the frequency range.

#### REFERENCE

- <sup>1</sup> ANDERSON, L. J.: "A Line Type of Microphone for Speech Pick-Up," *J. Soc. Mot. Pic. Eng.*, XXXVI (Feb., 1941), p. 309.

## NEW MOTION PICTURE APPARATUS

*During the Conventions of the Society, Symposiums on new motion picture apparatus are held, in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.*

### A LINE TYPE OF MICROPHONE FOR SPEECH PICK-UP\*

L. J. ANDERSON\*\*

The reduction of the line type of microphone<sup>1</sup> to a practical form is complicated by the fact that in order to secure useful directional characteristics at low frequencies, the microphone becomes extremely large and cumbersome. Even the use of delay in the pipe system and the use of a pressure-gradient pick-up device necessitates the use of lines whose length approaches one-half wavelength at the lowest frequency involved. Bearing in mind the fact that quite satisfactory speech pick-up can be obtained with a system whose response is limited to a band width of 150 to 5000 cycles, and, that in order to produce a microphone of reasonable portability the length could not exceed 6 feet, an investigation was made to see what might be accomplished in the way of directional characteristics.

For a simple line type, 6 feet long, with maximum response along the axis, the angle at 150 cycles will be about 160 degrees, which is rather broad, and at 5000 cycles will become far less than 30 degrees. Such variations in directional characteristics are undesirable since they represent differing response characteristics for points off the axis. Unless it is desired to complicate the structure considerably, the angle of response at 150 cycles must be accepted as a starting point. However, the extreme narrowness at higher frequencies may be eliminated by constructing the microphone in such a way that the effective length of the line becomes shorter with increasing frequency. In practice the theoretical ideal of having the reduction proportional to the frequency is approximated by dividing the microphone into three or more sections, with either electrical or acoustical filtering means. Further analysis of the problem indicates that dividing the response range into three bands will produce directional characteristics which do not vary too widely. The bands selected were, roughly, 200–750 cycles, 750–2100 cycles, and 2100–5000 cycles. The length of the section that is to function in each band is then chosen so that the product of the average frequency and the length is approximately constant from section to section. (See Figs. 1 and 2.)

The low-frequency response may be limited to the desired value of 150 cycles

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\*Presented at the 1940 Fall Meeting at Hollywood, Calif.; received October 15, 1940. (The Society is not responsible for statements by authors.)

\*\*RCA Manufacturing Co., Camden, N. J.



FIG. 1. (*Right*) Longitudinal view.FIG. 2. (*Left*) Side view.

by any one of several means. However, the simplest way in which the desired low-frequency cut-off may be obtained is through the use of a diaphragm-type pressure microphone in which the normal low-frequency response is obtained by a resonant circuit consisting of the case volume and an air mass in a tube connecting the case volume to the outside. By closing the tube, the stiffness of the moving system and case may be used to secure the low-frequency cut-off. While the cut-off so obtained is not rapid, it is sufficiently so to prevent accentuation of the lower frequencies due to the decreasing directivity. The upper cut-off frequency for the low and mid-frequency pipes is obtained by inserting in each pipe close to the pick-up unit a plug with a small hole. The inertance so introduced, in combination with the pipe impedance and the volume between the microphone diaphragm and the pipe termination, provides the desired cut-off. The cut-off at 5000 cycles for the high-frequency pipes is obtained by providing a small compliance between the microphone diaphragm and the ends of the pipes. No inertances are inserted in the high-frequency pipes.

Since only one microphone functions at the high-frequency end, two microphones in the mid-frequency range, and three microphones in the low-frequency



range, it is necessary to provide the individual tubes of the high and mid-frequency sections with suitable horns.

The high-frequency section is placed as close to the associated microphone unit as possible in order to avoid attenuation in the pipes. It consists of four pipes, each branching into three smaller pipes (totaling an area equal to that of the larger pipe). The resulting twelve openings are spaced 1 inch apart, making a line 11 inches long, which provides pick-up points sufficiently close for all practical purposes. These pipes are fitted with double-flare horns for the purpose mentioned above. The horn section nearest the pipe has a cut-off frequency of 750 cycles and a gain of 2:1 so as to function in combination with the mid-frequency horns. The second section of the horn was given a cut-off frequency of 2100 cycles and a gain of 5:1 to compensate for losses in the coupling to the microphone and in the microphone proper, due to the absence of diffraction effects, which are normally present. The mid-frequency section consists of six pipes, with openings spaced 2 inches apart, approximately 2 inches from the nearest high-frequency pipe. These tubes are fitted with horns having a cut-off frequency of 750 cycles and a

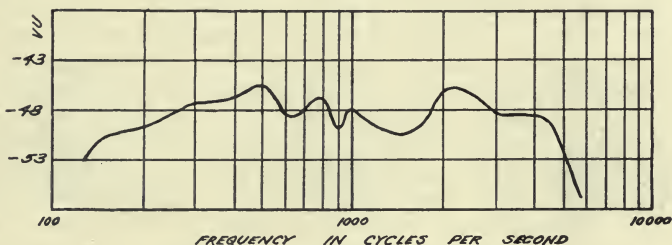


FIG. 3. Frequency response on axis.

gain of 2:1. Because of physical limitations imposed by the use of branched pipes and horns in the high-frequency section, the mid-frequency section contains the shortest tube of the entire assembly. The low-frequency section consists of a bundle of nine pipes, terminating at spacings to bring the overall length of the microphone to approximately 6 feet. The gains obtained with the horns specified are somewhat greater than necessary, but are advantageously used to secure increased sensitivity from the microphone. In the experimental model the desired response was obtained when the output transformers of the high and mid-frequency sections had about one-third the turn-ratio of the one used in the low-frequency section. Figs. 1 and 2 give a much clearer idea of the general arrangement.

Summarizing the operation of the microphone, we have the following: between 200 and 750 cycles, all the pipes and microphones are functioning, and the effective length of the line is approximately 6 feet. Between 700 and 2100 cycles, only the high and mid-frequency sections are functioning, by virtue of the inductance introduced into the low-frequency pipes. The loss of sensitivity due to the dropping of the one pick-up unit is compensated for by the 750-cycle sections of the horns on the high and mid-frequency lines. From 2100–5000 cycles, only the high-frequency pipes are in operation, because of the inductances inserted in low

and mid-frequency pipes. Above 5000 cycles, the response is attenuated as desired by the proper choice of compliance between the microphone diaphragm and the pipe ends.

The results of tests made on the experimental model are shown in Figs. 3 and 4, the data for which were obtained out of doors with the microphone approximately 28 feet from the sound-source. The agreement with theoretical predictions is generally good except at the lower frequencies where the directional characteristics are somewhat narrower than expected.

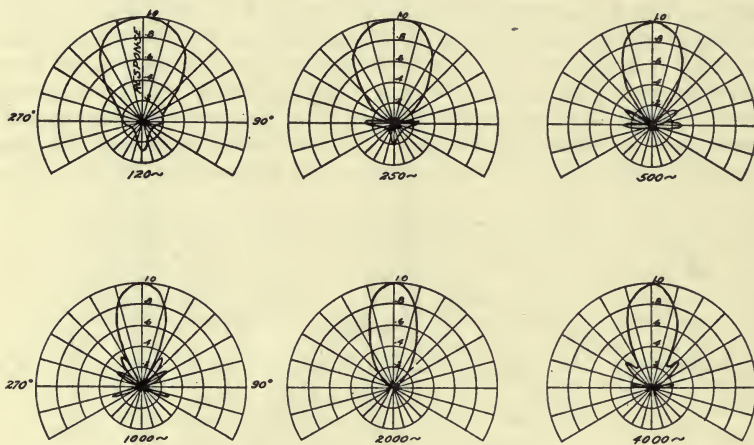


FIG. 4. Directional characteristics.

Observations regarding the performance under operating conditions are as yet relatively meager, but it appears that microphones of this type should offer a powerful new tool for the pick-up of speech under adverse conditions.

#### REFERENCE

<sup>1</sup> OLSON, H. F.: "Line Microphones," *J. Soc. Mot. Pic. Eng.*, XXXVI (Mar., 1941), p. 302.

#### DISCUSSION

MR. HOPPER: We have had some experience with a similar type of microphone, developed by the Bell Laboratories some years ago. It has similar directional properties. Two models were built, one five feet long, and one ten feet long. The 5-ft model was directional to 200 cycles, and the other to an octave lower. Using the microphone indoors on sets and stages, due to the fact that low-frequency troubles are usually predominant on sets, there was not sufficient directivity at low frequencies and the instrument did not function too satisfactorily. The rather large size of the device proved objectionable on a set congested with the usual picture equipment. For stage production use the response characteristic

should be rather like that of the average type of microphone normally used on the set, so that recordings made on either microphone will be sufficiently alike to permit direct intercutting of takes. Outdoors the instrument works more successfully because we are not so concerned with low-frequency reverberation or reflection from surrounding objects.

Have you had any experience with the microphone in wind? We found that the pipe structure used was rather susceptible to wind noise.

MR. RETTINGER: I have not had a great deal of experience with the microphone outdoors. I calibrated it outdoors, but made the tests when there was no wind, usually in the mornings.

MR. SKINNER: Is the size of the pipes very important? Could they be made smaller? Is a definite diameter required for each pipe?

MR. RETTINGER: There is no limit to the size of the tube that can be used, except that when the tube becomes too small there is a great deal of attenuation due to viscosity, which is negligible in this case, except perhaps at 5000 cycles. These tubes are  $\frac{1}{4}$  inch in diameter; the other tubes were  $\frac{3}{16}$  inch.

MR. SKINNER: By using more tubes could you not get a smoother response?

MR. RETTINGER: Yes, but there is a limit to the number of tubes that can be used without making the diameter of the microphone too great. The weight would also increase. The combined areas of the tubes come together into the small diameter of the microphone diaphragm, and the large change in area represents an acoustic mismatch, which, of course, is not desirable.

MR. WOLFE: In connection with Mr. Hopper's remarks, we unfortunately have had practically no experience with this microphone to date. It came into our hands only a few days ago and we do not know what problems will be encountered. We were aware of the problems that were encountered with the Bell Laboratories device at the time it was developed, and I feel reasonably sure that Dr. Olson and Mr. Anderson have taken them into account, so I believe that the variation from the directional characteristic when used indoors will not be as great as was previously experienced.

The quality of this microphone is not as good as that of the microphone we commonly use today in recording for motion pictures. But it does seem, if this directional frequency characteristic can be maintained, that under difficult pick-up conditions the overall frequency response, when all reflections and reverberations are taken into account, may be definitely better and more nearly like the quality received by a normal microphone under good pick-up conditions.

MR. TASKER: I might mention that some of us still use concentrators in really difficult spots—not often, but occasionally. They are certainly bad.

Are delay circuits used in the longer tubes of this microphone?

MR. RETTINGER: No. The tubes could have been made shorter, but it was not felt that delay tubes would be of sufficient advantage in this microphone.

MR. CRABTREE: To get the maximum efficiency is it necessary to sight the microphone like a rifle?

MR. RETTINGER: It is helpful. The microphone has a reception angle of 30 degrees, in which sound is received with uniform intensity.

MR. CRABTREE: Does it have a telescopic sight? What is the distance at which it works most efficiently?

MR. RETTINGER: It is operated at a little greater distance than the ordinary



microphone, due to the narrow angle of pick-up. To cover a wider area it must be moved farther from the sound-source.

MR. CRABTREE: Suppose you sighted the rifle at a particular person in a large audience, would you get a better response than with the use of a concentrator?

MR. RETTINGER: The microphone is not so directional as to require an actual sight on the object. Most of the energy of speech centers around 500 cycles, at which frequency the microphone is still directional, but not so highly so that you would not be able to make a good guess at the direction in which to point it.

MR. TASKER: Since the patterns for the various frequency ranges are similar, broadening somewhat at the lower frequencies, the one for 2000 cycles may be taken as typical. It is apparent if the subject is anywhere within approximately 30 degrees, there is substantially maximum response at that frequency. The change in response is about two db. If, however, the subject were standing much to either side of the 30-degree angle, the amount of sound at 2000 cycles would be very low indeed. It is simply necessary to sight this angle of 30 degrees at the person who is speaking.

MR. CRABTREE: What is maximum range of satisfactory operation?

MR. RETTINGER: The microphone can be operated at the same distance as any other microphone. As a matter of fact, its sensitivity is higher than that of any other type. That was found out also by the Bell Laboratories people when they made their first investigations, using a 618A microphone. The sensitivity at all frequencies went up 5 db.

MR. WOLFE: These directional characteristics were measured at a distance of 27 feet from the source. In normal practice we endeavor to keep the microphone within five feet of the speaker. That is not always possible, but it is a reasonable distance for operating our present recording types of microphone. In public address work we put them much closer to the subject.

With this type of microphone we would normally expect to work at a distance that would be perhaps three times as great, or 15 to 25 or 30 feet from the subject.

Dr. Olson has described<sup>1</sup> other microphones having similar directional characteristics but developed for a somewhat different purpose. They were designed to have a better frequency characteristic than this microphone, because the intention was to use them, in some cases, for pick-up of symphony orchestras and similar material. Such a microphone was built and used in the Metropolitan Opera House in New York, where it was located on the balcony at a distance of 100 to 150 feet from the orchestra.

It is a little difficult to define the distance at which the microphone can be operated, as that depends entirely upon the circumstances. We can, however, say that its normal operating distance is two or three times that of the regular types of microphone that have been used. This microphone, or one similar to it, was used at the Republican and Democratic Conventions this year by NBC. They had very good results in picking up speech from the floor. The microphone must frequently have been 50 to 75 feet from the speaker.



## CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

*The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Biblofilm Service, Department of Agriculture, Washington, D. C.*

### American Cinematographer

22 (February, 1941), No. 2

- |  |           |
|--|-----------|
| Fantasound—Disney's New Sound System (pp. 58–59, 80, 81)         | W. STULL  |
| Cut with Script and Camera Says Director Rene Clair (pp. 60, 82) | W. STULL  |
| New Multiplex Lamp (pp. 61, 82)                                  | T. GAUDIO |

### Educational Screen

20 (January, 1941), No. 1

- |  |             |
|--|-------------|
| Motion Pictures—Not for Theaters (pp. 15–17), Pt. 23 | A. E. KROWS |
|--|-------------|

### Electronics

14 (January, 1941), No. 1

- |  |             |
|--|-------------|
| Sound in Motion Pictures (Review 1927–1939) (pp. 17–19, 73–76) | N. LEVINSON |
|--|-------------|

### International Projectionist

15 (December, 1940), No. 12

- |  |                |
|--|----------------|
| “Fantasound” Soundheads and Amplifiers (pp. 18–20) | C. S. ASHCRAFT |
|--|----------------|

### Kinotechnik

22 (October, 1940), No. 10

- |   |              |
|---|--------------|
| Vergleichende Messung der Wirkung verschiedener Schutzbehandlungsmethoden auf Filmbildschichten und deren Trager (Comparative Measurements of the Effect of Different Kinds of Protective Treatment on the Emulsion and in the Film Base) (pp. 141–143) | W. FERMAZIN  |
| Der AFIFA—Pruffilm 40/16T für Schmaltonfilmapparaturen (AFIFA Test Film 40/16T for Substandards Sound Cameras) (pp. 143–145)  | H. ECKELMANN |
| 22 (November, 1940), No. 11   |              |
| Agfacolor—Der deutsche Farbenfilm (Agfacolor—the German Color Film) (pp. 151–154)   | H. BECK      |
| Lichtstarke und relative Öffnung von Kine-Objektiven  |              |

(Light Intensity and Relative Aperture of Motion Picture Lenses) (pp. 154-157)

A. KOCHS

**Kinematograph Weekly**

287 (January 9, 1941), No. 1760

Revolutionary Matte Process, Applicable to Monochrome and Colour (pp. 21-22)

**Motion Picture Herald**

142 (February 1, 1941), No. 5

Television Brought to Theater by RCA Large Screen Showing (pp. 30-32)

**Photographische Industrie**

38 (November 27, 1940), No. 48

Neue Entwickler für Kinofilm (New Developer for Motion Picture Film) (pp. 721-722)

38 (December 11, 1940), No. 50

Rechnerische Bestimmung von Regenerierungslosungen für Maschinen-Entwickler (Mathematical Determination of Regeneration Solutions for Machine Developers) (pp. 753-754)

## 1941 SPRING CONVENTION

### SOCIETY OF MOTION PICTURE ENGINEERS

THE SAGAMORE HOTEL  
ROCHESTER, NEW YORK  
MAY 5th-8th, INCLUSIVE

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**HEADQUARTERS**

The headquarters of the Convention will be the Sagamore Hotel, where excellent accommodations and moderate rates are assured. A reception parlor will be provided as headquarters for the Ladies' Committee.

Hotel reservation cards will be mailed to the members of the Society early in April. They should be filled out and mailed immediately to the Sagamore Hotel so that suitable accommodations may be reserved, subject to cancellation if unable to attend the convention.

The following European-plan day rates are extended by the Sagamore Hotel to Society members and guests attending the Convention (all rooms are outside rooms with bath):

Room for one person	\$3.00 to \$5.00
Room for two persons, double bed	4.50 to 6.00
Room for two persons, twin beds	6.00 to 7.00
Suite accommodations, one to four persons	12.00 and up

The following hotel garage rates will be available to SMPE delegates and guests who motor to the Convention: 24-hr. inside parking, 75¢; outside parking (daily), 25¢.

The colorful *Sagamore Room* on the main floor of the Hotel offers special breakfast, luncheon, and dinner menus at moderate prices.

Golfing privileges at several Rochester country clubs may be arranged for either by the hotel management or at the SMPE registration headquarters.



## REGISTRATION

Convention registration and information headquarters will be located on the Sagamore Hotel roof, adjacent to the *Glass House*, where all technical sessions and symposiums will be held.

Members and guests attending the Convention will be expected to register, and so help to defray the Convention expenses. Convention badges and identification cards will be provided for admittance to all regular and special sessions during the Convention. The identification card will also be honored through the courtesy of Loew's Theaters, Inc., at Loew's *Rochester* Theater and, through the courtesy of Monroe Amusements, Inc., at the *Palace*, *Regent*, and *Century* Theaters.

Group visits to various plants in Rochester and vicinity may be arranged at the Registration Desk.

## TECHNICAL SESSIONS

All the technical sessions of the Convention will be held in the *Glass House* on the roof of the Sagamore Hotel with the exception of Wednesday evening, as described below. Members should note that the banquet, which at past conventions has always been held on Wednesday evening, this time has been scheduled for Tuesday evening to permit holding a special meeting on Wednesday evening at the *Eastman* Theater.

Wednesday, May 7th, will be devoted to a joint meeting of the Acoustical Society of America and the SMPE, consisting of a symposium of papers by engineers of the Bell Telephone Laboratories in the morning and afternoon. In the evening a demonstration of stereophonic sound will be given by the Bell Telephone Laboratories at the *Eastman* Theater.

## LUNCHEON AND BANQUET

The usual Informal Get-Together Luncheon for members, their families, and guests will be held in the *Starlight Room* on the hotel roof on Monday, May 5th, at 12:30 P. M.: short addresses by prominent speakers; names to be announced later. Luncheon and banquet tickets should be procured when registering.

The 48th Semi-Annual Banquet and Dance will be held in the *Starlight Room* on the hotel roof on Tuesday evening, May 6th, at 7:30 P. M.: music and entertainment. Banquet tickets should be procured and tables reserved at registration headquarters by noon of Tuesday, May 6th.

## LADIES' PROGRAM

Mrs. C. M. Tuttle, *Convention Hostess*, and members of her Committee are arranging a very attractive program of entertainment for the ladies attending the Convention. A reception parlor will be provided for the use of the Committee during the Convention.

## SPRING CONVENTION

## PROGRAM

*Monday, May 5th*

- 9:00 a. m. *Sagamore Hotel Roof*  
Registration
- 9:30 a. m.-12:00 *Glass House, Hotel Roof*  
Technical session
- 12:30 p. m. *Starlight Room, Hotel Roof*  
Get-Together Luncheon for members, their families, and guests. Brief addresses by several prominent speakers
- 2:00 p. m. *Glass House, Hotel Roof*  
Technical session
- 8:00 p. m. *Glass House, Hotel Roof*  
Technical session

*Tuesday, May 6th*

- 9:00 a. m. *Sagamore Hotel Roof*  
Registration
- 9:30 a. m. *Glass House, Hotel Roof*  
Society Business  
Technical session
- 12:30 p. m. Luncheon period  
Program for this afternoon to be announced later
- 7:30 p. m. *Starlight Room, Hotel Roof*  
Semi-Annual Banquet and Dance of the SMPE: addresses and entertainment: music, dancing, and entertainment

*Wednesday, May 7th*

- 10:00 a. m. *Glass House, Hotel Roof*  
Technical session
- 12:30 p. m. Luncheon period
- 2:00 p. m. *Glass House, Hotel Roof*  
Stereophonic sound papers session
- 8:00 p. m. *Eastman Theater*  
Stereophonic sound demonstration for the SMPE Convention and invited groups. Admission only by SMPE identification card, or special invitation card

*Thursday, May 8th*

- 10:00 a. m. *Glass House, Hotel Roof*  
Technical session
- 12:30 p. m. Luncheon period
- 2:00 p. m. *Glass House, Hotel Roof*  
Technical and business session

## ADJOURNMENT

W. C. KUNZMANN,  
*Convention Vice-President*

## SOCIETY ANNOUNCEMENTS

### ATLANTIC COAST SECTION

At a meeting held at the Hotel Pennsylvania, New York, on February 19th, attention was given to the current motion picture activities in relation to the National Defense Program. Two papers, illustrated by 16-mm motion pictures, were presented as follows:

#### Civilian Aspects of the Defense Program

by

Mr. Arch E. Mercy, Special Assistant, Advisory Commission to the Council on National Defense, Washington, D. C.

#### The Production of Training Films

by

Lt. Col. M. E. Gillette, Signal Corps, Photographic Section, Officer in Charge of Production of Motion Picture Training Films for the U. S. Army.

The meeting was very well attended and aroused considerable interest in the government motion picture activities. A lively question and answer period followed the presentations.

### AMENDMENTS TO THE BY-LAWS

The proposed amendments to the By-Laws given below have been approved by the Board of Governors on the dates indicated. In accordance with the procedure for amending the By-Laws, these proposals are published herewith, and are to be submitted to the membership of the Society at the business meeting to be held at the Spring Convention at Rochester.

*By-Law IV, Sec. 4(b).*—To the list of standing committees of the Society appointed by the Engineering Vice-President shall be added:

Committee on Process Photography

Committee on Preservation of Film

The latter committee has been functioning for a number of years, but has not been specifically mentioned in the By-Law. (Approved by the Board of Governors, Oct. 20, 1940.)

*By-Law VII, Sec. 1.*—In the procedure for nominating and electing officers of the Society, it is at present stipulated that:

The Secretary shall then notify these candidates of their nomination in order of nominations and request their consent to run for office.

The proposal is to delete the latter part of this sentence so that it will read:

The Secretary shall then notify these candidates of their nomination. (Approved by the Board of Governors Oct. 20, 1940.)

*By-Law XI, Sec. 6.*—This By-Law outlines the procedure for nominating and electing the officers and managers of the local sections of the Society. The present wording is as follows:

The remainder of the procedure shall be in accordance with the procedure specified for the election of officers of the General Society as described in By-Law VII, Section 1(a), the word *Manager* being substituted for the word *Governor*.

Instead of allowing the procedure to be implicit, by the substitution of the word *Manager* for the word *Governor*, it was felt that it would be better and more accurate if the procedure were written out in full, following, as far as possible, the procedure for electing officers of the General Society. In addition to the advantage of being explicit, this procedure must differ slightly in wording in view of the different compositions of the Board of Governors (for the General Society) and the Board of Managers (for the Local Sections). The proposed wording is as follows:

The Chairman of the Section shall then notify these candidates of their nomination. From the list of acceptances, not more than two names for each vacancy shall be selected by the Board of Managers and placed on a letter ballot. A blank space shall be provided on this letter ballot under each office, in which space the names of any Active, Fellow, or Honorary members other than those suggested by the Board of Managers may be voted for. The balloting shall then take place.

The ballot shall then be enclosed in a blank envelope which is enclosed in an outer envelope bearing the local Secretary-Treasurer's address and a space for the member's name and address. One of these shall be mailed to each Active, Fellow, and Honorary member of the Society, residing in the geographical area covered by the Section, not less than forty days in advance of the annual Fall Convention.

The voter shall then indicate on the ballot one choice for each office, seal the ballot in the blank envelope, place this in the envelope addressed to the Secretary-Treasurer, sign his name and address on the letter, and mail it in accordance with the instructions printed on the ballot. No marks of any kind except those above prescribed shall be placed upon the ballots or envelopes.

The sealed envelope shall be delivered by the Secretary-Treasurer to his Board of Managers at a duly called meeting. The Board of Managers shall then examine the return envelopes, open and count the ballots, and announce the results of the election.

The newly elected officers and managers shall take office on the January 1st following their election.

#### ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee at the General Office of the Society, the following applicants for membership were admitted to the Associate grade:



- ABBOTT, F. RODERIC  
542 South Broadway,  
Los Angeles, Calif.
- BALL, W. S.  
1256 Howard St.,  
San Francisco, Calif.
- BECKER, M. E.  
Photo and Sound, Inc.,  
153 Kearny St.,  
San Francisco, Calif.
- BERG, B.  
1816 Silverwood Terrace,  
Los Angeles, Calif.
- BOYD, J. M.  
2013 S. Vermont Ave.,  
Los Angeles, Calif.
- BURNS, B. J.  
1017 N. Las Palmas Ave.,  
Hollywood, Calif.
- BURROUGHS, G. S.  
33-41, 73rd St.,  
Jackson Heights, L. I.,  
N. Y.
- BUSSELL, J.  
6342 W. 6th St.,  
Los Angeles, Calif.
- CARROLL, R.  
1935 Fairburn Ave.,  
West Los Angeles, Calif.
- CHERNEY, P.  
112-15, 72nd Rd.,  
Forest Hills, N. Y.
- CLIFTON, E. D.  
600 S. York St.,  
Mechanicsburg, Pa.
- COLSON, P. D.  
503 Ware Ave.,  
East Point, Ga.
- CONANT, R. W.  
3774 Effingham Pl.,  
Hollywood, Calif.
- CURTIS, H. K.  
9021 Dicks St.,  
West Hollywood, Calif.
- DENIS, ANDRE  
8630 Berri St.,  
Montreal, P. Q.
- DEWEY, WM.  
126 Langdon St.,  
Madison, Wis.
- DUKE, D. W.  
Cinema Dept., Univ. of S. Calif.,  
Box 326, Los Angeles, Calif.
- DUNN, L. G.  
345 N. Formosa Ave.,  
Hollywood, Calif.
- DYATT, I. B.  
525 Monroe St.,  
Corvallis, Ore.
- EGLINTON, WM.  
780 N. Gower St.,  
Hollywood, Calif.
- ELLS, F. C.  
272 Grant St.,  
Pasadena, Calif.
- FISHER, J. L.  
1701 N. Michigan Ave.,  
Pasadena, Calif.
- FREISLEBEN, W. H.  
170 Ninth St.,  
San Francisco, Calif.
- GEPHART, W. E., JR.  
4537 Placidia Ave.,  
North Hollywood, Calif.
- GOLDFARB, H.  
8139 W. 4th St.,  
Los Angeles, Calif.
- GUNN, R. L.  
Twentieth Century-Fox Corp.,  
10201 W. Pico Blvd.,  
Los Angeles, Calif.
- HAINES, A.  
Pathe Labs. of Calif., Inc.,  
6823 Santa Monica Blvd.,  
Los Angeles, Calif.
- HARRISON, W. H.  
Harrison Projector Co.,  
8351 Santa Monica Blvd.,  
Hollywood, Calif.
- HAUSER, F.  
1544 Midvale Ave.,  
West Los Angeles, Calif.
- HIRSCH, T.  
1514 S. Beverly Drive,  
Los Angeles, Calif.

- HYNE, A. D.  
1429—23rd Ave.,  
San Francisco, Calif.
- JACKSON, A.  
3662 Dunn Drive,  
Los Angeles, Calif.
- JAFFEE, P.  
9125 West 25th St.,  
Los Angeles, Calif.
- JONES, H. V.  
6819—11th Ave.,  
Los Angeles, Calif.
- THORN, T. K.  
Rialto Bioscope,  
Senen,  
Batavia, Java
- LANGENBACHER  
5909 N. Kilbourne St.,  
Chicago, Ill.
- LAUBE, G.  
1554 S. Manhattan Pl.,  
Los Angeles, Calif.
- LAW, E. A.  
544 N. Alta Vista Blvd.,  
Hollywood, Calif.
- LEPKO, N. P.  
c/o W. T. Crespinel,  
4248 Cahuenga Blvd.,  
N. Hollywood, Calif.
- LODEN, B. M.  
2381 Peachtree Rd.,  
Atlanta, Ga.
- LOEWENSTEIN, F.  
106 W. 87th St.,  
New York, N. Y.
- LUND, S. D.  
3441 Wonderview Dr.,  
Hollywood, Calif.
- MAHONEY, G. E.  
12040 Otsego St.,  
N. Hollywood, Calif.
- MARCUCCI, SIMONE  
V. G. Uberti 7,  
Milano, Italy
- MARTIN, R. C.  
10341 Rossbury Pl.,  
Los Angeles, Calif.
- MCLEAN, F. R.  
Box C,  
Coulterville, Ill.
- MILLER, A. J.  
310 Edgewood Ave.,  
West Englewood, N. J.
- MILLER, H. M.  
526 Arbramar Ave.,  
Pacific Palisades, Calif.
- NEWMAYER, R. H.  
1703 Jefferson St.,  
Philadelphia, Pa.
- NOBLE, J. V.  
310 N. 40th St.,  
Philadelphia, Pa.
- PETERSON, E. J.  
1216 N. Kenmore St.,  
Los Angeles, Calif.
- PRIMI, J.  
202—09, 50th Ave.,  
Bayside, L. I., N. Y.
- ROBERTSON, B. C.  
11043 Kling St.,  
N. Hollywood, Calif.
- RUNK, J. S.  
1511 Clark Ave.,  
Burbank, Calif.
- SANDIFORD, B.  
2859 Walnut St.,  
Huntington Park, Calif.
- SHAFFER, L. W.  
Box 43,  
Shrewsbury, Pa.
- SHANER, V. C.  
Eastman Kodak Company,  
6706 Santa Monica Blvd.,  
Hollywood, Calif.
- SILVERMAN, L. B.  
1517 Sherbourne Dr.,  
Los Angeles, Calif.
- SOMES, G. W.  
1700 Montana Ave.,  
West Los Angeles, Calif.
- SPACE, K. F.  
40 E. 17th St.,  
Brooklyn, N. Y.

STOEN, PER

1010 E. 42nd St.,  
Brooklyn, N. Y.

SWAIN, J. J.

1548 N. Orange Grove St.,  
Hollywood, Calif.

SWEENEY, E. G.

3535 N. Lakewood St.,  
Chicago, Ill.

THORN, T. K.

Rialto Bioscope,  
Senen,  
Batavia, Java

TIFFANY, E. J.

14646 Magnolia Blvd.,  
Van Nuys, Calif.

VAN LEUVEN, J. F.

8928 Santa Monica Blvd.,  
Los Angeles, Calif.

VAN NIMAN, R. T.

c/o Motiograph, Inc.,  
4431 W. Lake St.,  
Chicago, Ill.

WADE, N. G.

Massachusetts Institute of Tech.,  
Cambridge, Mass.

WEIR, D. D.

Eastman Kodak Company,  
6706 Santa Monica Blvd.,  
Hollywood, Calif.

WEXLER, SY

901 E. 179th St.,  
New York, N. Y.

WORK, L. P.

119 S. Destnedge Ave.,  
Kalamazoo, Mich.

WYBROW, E.

10435 Dunleer Drive,  
Los Angeles, Calif.

In addition, the following applicants have been admitted to the Active grade:

BOYLE, J. W.

1207 No. Mansfield Ave.,  
Hollywood, Calif.

DAVIDSON, J. C.

461 S. Rexford Drive,  
Beverly Hills, Calif.

GAGE, F. W.

c/o Warner Brothers Pictures, Inc.,  
Burbank Calif.

GLENNAN, T. KEITH

Paramount Pictures, Inc.,  
5451 Marathon Street,  
Hollywood, Calif.

KELLEY, E. A.

2228 Holly Drive,  
Hollywood, Calif.

LUKENS, C. P.

408 West Cienega St.,  
San Dimas, Calif.

SLOAN A.

Washington Theater Bldg.,  
Washington, N. J.

The following members have been transferred from Associate to Active grade

ALBIN, F. G.

United Artists Studio Corp.,  
1041 N. Formosa Ave.,  
Hollywood, Calif.

SOLOW, S. P.

Consolidated Film Industries, Inc.,  
959 Seward Street,  
Hollywood, Calif.

SLYFIELD, C. O.

3216 W. 78th Place,  
Los Angeles, Calif.

WORRALL, G. H.

Mitchell Camera Corp.,  
665 N. Robertson Blvd.,  
West Hollywood, Calif.

## BACK NUMBERS OF THE TRANSACTIONS AND JOURNALS

Prior to January, 1930, the *Transactions* of the Society were published quarterly. A limited number of these *Transactions* are still available and will be sold at the prices listed below. Those who wish to avail themselves of the opportunity of acquiring these back numbers should do so quickly, as the supply will soon be exhausted, especially of the earlier numbers. It will be impossible to secure them later on as they will not be reprinted.

	No.	Price		No.	Price		No.	Price
1924	{19	\$1.25	1926	{25	\$1.25	1928	{33	\$2.50
	{20	1.25		{26	1.25		{34	2.50
	{21	1.25		{27	1.25		{35	2.50
1925	{22	1.25	1927	{28	1.25	1929	{36	2.50
	{23	1.25		{29	1.25		{37	3.00
	{24	1.25		{32	1.25		{38	3.00

Beginning with the January, 1930, issue, the JOURNAL of the Society has been issued monthly, in two volumes per year, of six issues each. Back numbers of all issues are available at the price of \$1.00 each, a complete yearly issue totalling \$12.00. Single copies of the current issue may be obtained for \$1.00 each. Orders for back numbers of *Transactions* and JOURNALS should be placed through the General Office of the Society and should be accompanied by check or money-order.

## SOCIETY SUPPLIES

The following are available from the General Office of the Society, at the prices noted. Orders should be accompanied by remittances.

*Aims and Accomplishments*.—An index of the *Transactions* from October, 1916, to December, 1929, containing summaries of all articles, and author and classified indexes. One dollar each.

*Journal Index*.—An index of the JOURNAL from January, 1930, to December, 1935, containing author and classified indexes. One dollar each.

*Motion Picture Standards*.—Reprints of the *American Standards and Recommended Practice* as published in the March, 1941, issue of the JOURNAL; 50 cents each.

*Membership Certificates*.—Engrossed, for framing, containing member's name, grade of membership, and date of admission. One dollar each.

*Journal Binders*.—Black fabrikoid binders, lettered in gold, holding a year's issue of the JOURNAL. Two dollars each. Member's name and the volume number lettered in gold upon the backbone at an additional charge of fifty cents each.

*Test-Films*.—See advertisement in this issue of the JOURNAL.



# JOURNAL

## OF THE SOCIETY OF

# MOTION PICTURE ENGINEERS

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Volume XXXVI

April, 1941

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# JOURNAL

## OF THE SOCIETY OF

### MOTION PICTURE ENGINEERS

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SYLVAN HARRIS, EDITOR

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- \*R. O. STROCK**, 35-11 35th St., Astoria, L. I., N. Y.

\*Term expires December 31, 1941.

\*\*Term expires December 31, 1942.

## A 200-MIL VARIABLE-AREA MODULATOR \*

R. W. BENFER AND G. T. LORANCE\*\*

**Summary.**—A modulator using a new vibrating-mirror unit has been developed for recording double-width variable-area sound-track. The noise-reduction shutter is at the slit, making it possible to record, with noise-reduction, class A push-pull track comprising two standard bilateral tracks, one of which is located in accordance with the dimensional standards for single track. While this has been its principal use to date, it is readily adaptable for other types of track. A visual monitor shows operation of the noise-reduction shutter and the amplitude of signal modulation in both directions from the base-line with a positive indication of peak over-load. An exposure meter is included to serve as a check on lamp current and track balance. The light-source is a tungsten filament lamp which will properly expose fine-grain emulsions to "white" light or standard emulsions through an ultraviolet filter.

Equipment has been available and in use for some time for the recording of double-width or 200-mil push-pull variable-density sound-track. The generally satisfactory results obtained by this method have encouraged the development of equipment for making the same advantages available for the recording of variable-area track. The modulator described herein has been used for recording double-width class A push-pull variable-area sound-track although it is readily convertible to the recording of other types of sound-track.

If double-width track is combined with push-pull recording, the following advantages are realized.

- (1) The signal-to-noise ratio of a sound-on-film record is increased 3 db.
- (2) Clipping is reduced because faster operation of noise-reduction is permissible.
- (3) "Hush-hush" is reduced because, with increased speed of noise-reduction, less margin is required.
- (4) Distortion is reduced by the balancing action of push-pull.
- (5) Film processing is less critical for a given degree of distortion.

Also, if one of the halves of the push-pull track is located in accordance with single-track standards the double-width push-pull track

---

\* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received December 12, 1940.

\*\* Electrical Research Products, Inc., Hollywood, Calif.

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Also, if one of the halves of the push-pull track is located in accordance with single-track standards the double-width push-pull track

---

\* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received December 12, 1940.

\*\* Electrical Research Products, Inc., Hollywood, Calif.

can be handled on standard reproducing equipment for such purposes as cutting and editing, although under these circumstances the operation of the noise-reduction system may be audible and distortion may be noticeable.

The dimensions and location of the sound-track recorded by this modulator are shown in Fig. 1, the dark areas corresponding to the exposed areas on the negative. The track is shown for three condi-

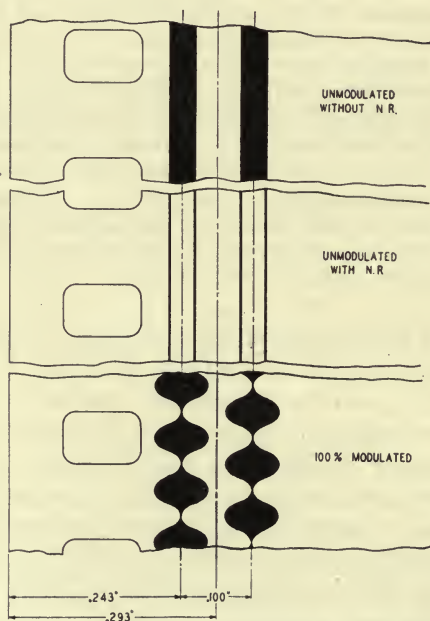


FIG. 1. Dimensions and location of sound-track.

tions: (1) unmodulated without noise-reduction; (2) unmodulated with noise-reduction; (3) completely modulated with noise-reduction shutter withdrawn by action of the signal.

A plan of the optical system less the visual monitor is shown schematically in Fig. 2.

The light-source is a 10-volt, 7.5-ampere or a 10.5-volt, 7.8-ampere curved-coil filament lamp. The condenser lens is a high-aperture single-element lens with aspheric surfaces. The combination of condenser and relay lens completely fills the vibrator mirror with an image of the filament. The mask, which provides the modulating edges, is

adjacent to the condenser lens and is curved to conform to the curvature of field characteristics of the relay lens. An image of the mask, magnified 1.5 times, is formed by the relay lens at the slit.

Light to form the image of the mask must be reflected by the mirror of the modulating unit, which is positioned so that the axis of the reflected beam is at an angle of 30 degrees with the axis of the incident beam. To modulate the sound-track the mirror vibrates about a horizontal axis, thereby moving the image of the mask triangles up and down across the slit. The mirror is the aperture stop of the system. The lamp, condenser lens, and relay lens are designed to supply all the light-rays that can be passed by the mirror, collector, slit, and objective lens onto the film.

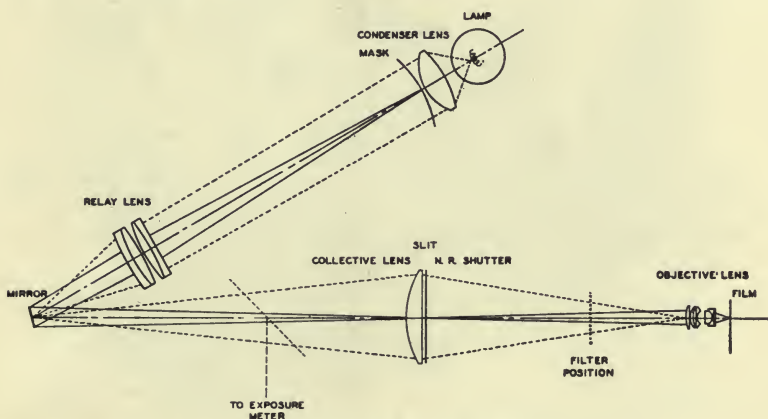


FIG. 2. Plan of optical system (less visual monitor).

The slit is accurately engraved in the silvered surface of a thin glass "flat," which is cemented to the plane surface of the collector lens, the convex side of which faces the mirror. This provides protection by glass on both sides of the slit, thus sealing it against dirt. The glass surfaces can be cleaned easily with no risk to the slit edges. A matte surface is provided by this construction on which the image of the mask triangles is made clearly visible.

Noise-reduction is obtained by intercepting the light emerging from the slit with a shutter which is moved into the light-beam in accordance with the currents from the noise-reduction circuit. This location of the noise-reduction shutter was chosen in order to obtain the advantages of a bilateral track in each of the two halves of the push-pull track.

The objective lens, working at a reduction of 8:1, projects onto the film a slit image, the nominal dimensions of which are 0.200 inch by 0.00025 inch. Two appropriately corrected, interchangeable objectives are available, one for the exposure of fine-grain emulsion to "white" light and the other for the exposure of standard emulsions to "ultraviolet" light. Both lenses have a working speed on the film side of  $f/2.0$  for their full circular apertures. Either of the previously mentioned lamps, operated at less than rated current and used in this system with the appropriate objective lens, will properly expose the films mentioned.

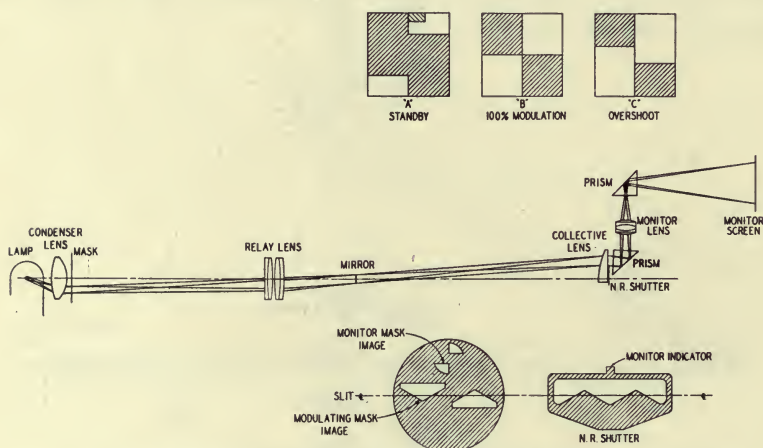


FIG. 3. Vertical section, unfolded, with diagrams of masks, noise-reduction shutter, and visual monitor patterns.

In case a filter, such as the Corning 584, is used, it is mounted near the objective lens on the side toward the slit. This location, near the lens, minimizes the effects of filter irregularities and dust because of its "out-of-focus" position, and it in no way interferes with visual observation of any operation or adjustment.

The light normally incident on the slit can be diverted to an exposure meter by swinging a mirror into the position indicated.

Fig. 3 is a vertical section through the optical axis showing an unfolded optical schematic as if the mirror were a transparent aperture. The visual monitor edges of the mask are imaged by the relay lens at an aperture in the plane of the slit above the image of the modulating edges. An indicator on the noise-reduction shutter intercepts some



of this light and is imaged, along with the image of the mask, on the visual monitor screen which is located conveniently several inches above the optical axis of the recording beam. The light is directed and the magnified image is formed by the combination of two prisms and a lens as indicated. This image shows the position of the noise-reduction shutter and indicates amplitude of signal modulation.

Illustrated at *A* (Fig. 3) is the monitor image in "standby" position. The edges of the shadow band are defined, respectively, by the peak amplitude of each half of the signal wave and travel in opposite di-

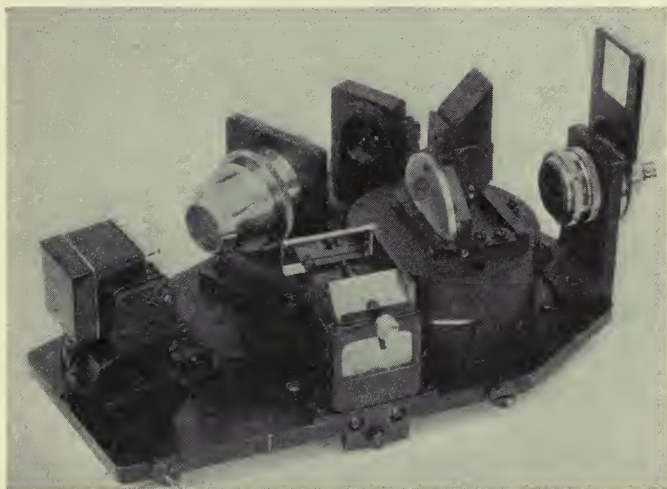


FIG. 4. Modulator, cover removed.

rections, thus decreasing the shadow width with an increasing amplitude of signal until, at 100 per cent modulation, the two edges are coincident and the shadow band disappears as illustrated at *B*. At higher amplitudes the edges pass each other, thus giving an instantaneous indication of overshooting, which can be evaluated by reference to an index on the monitor screen. The pattern for a peak overshoot is shown at *C* (Fig. 3).

Fig. 4 is a photograph of the modulator with the cover removed. The lamp, the condenser lens, and the masks comprise a unit assembly which includes adjustments for positioning and focusing the lamp filament on the vibrator mirror. Lateral adjustment of the two modulating mask triangles permits registering their images with the

noise-reduction shutter at the slit, and rotational adjustment permits control of the width of the unmodulated track. The width of the monitor mask can be adjusted to agree with the limits for a fully modulated track.

The objective and relay lenses are provided with focusing mounts in which the lenses may be moved along the optical axis without rotation and which permit adjustment and locking without the use of tools.

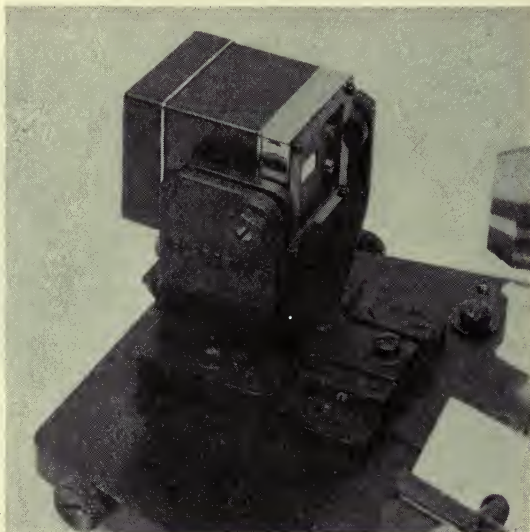


FIG. 5. Vibrator unit and cradle assembly.

A push-button-controlled deflector intercepts the light normally incident on the slit and directs it to the sensitive surface of a General Electric light-meter. The mask triangles are imaged on this surface and a selector is provided so that the illumination available for the exposure of each track as well as the total of both tracks can be read on the meter. Apertures are provided in each half of the beam to adjust the meter for equal deflections when the two track densities are identical. Release of the deflector control-button automatically restores the light-path to the recording position.

Fig. 5 is a photograph of the vibrator unit mounted in a cradle assembly which provides pivots on the horizontal and vertical axes of the mirror. These adjustments are independent and permit regis-

tering the mask images with the noise-reduction shutter to obtain symmetrical bias lines. Vibrator units are interchangeable and readily aligned for operation by reference to index marks on the visual monitor screen. Operation of a "quick-tilt" lever rotates the mirror about its horizontal axis to expose one track to its full width. The vibrator mirror automatically returns to "standby" position when the "quick-tilt" lever is released, thus making it convenient to expose laboratory test strips whenever desired.

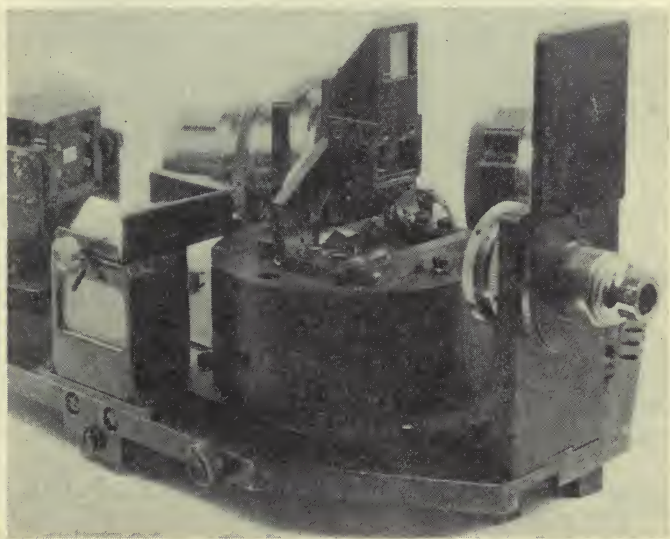


FIG. 6. Visual monitor, noise-reduction shutter, and slit assembly.

Fig. 6 is a photograph of the visual monitor, noise-reduction shutter, and slit assembly. Adjustments are provided that permit aligning the shutter parallel to and in correct register with the slit openings. Adjustments for azimuth relative to the film are also provided. The visual monitor optical system is a unit assembly supported by the slit mounting bracket. Its upper prism can be positioned at 90-degree intervals so that the monitor screen can be located in any one of four positions. The noise-reduction unit is an electrodynamic structure comprising a permanent magnet to supply the field and a moving coil for driving the shutter. Springs, one on each end of the magnetic structure, are rigidly connected by a rod through the center pole-piece. This rod carries the moving coil and is extended upward to drive the



shutter. The shutter is contoured to provide two opaque triangles for noise-reduction and the indicator imaged on the visual monitor screen. The moving coil of the noise-reduction shutter was designed



FIG. 7. Complete modulator, covered.

to operate within the power output limits of present noise-reduction circuits and will operate at attack speeds of 8 milliseconds or more as determined by the constants of the noise-reduction circuit.

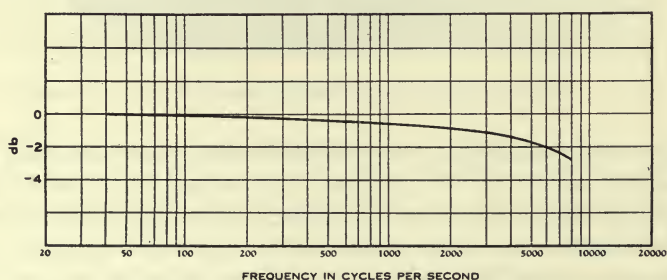


FIG. 8. Average "U. V." print response ("U. V." negative) for constant amplitude of mirror vibration.

Fig. 7 shows the modulator enclosed in its protective cover, which is removable to provide access to the adjustments necessary for installation. The controls essential to recording, such as the "quick-tilt" lever, the "standby" locking adjustment on the vibrator cradle,



and the controls for the exposure meter are accessible for operation without removing the cover. The entire unit rests on a sub-plate with a tongue-and-groove screw-thread adjustment for lateral positioning of the optical axis in reference to the film. This adjustment moves the entire modulator parallel to the film surface and does not affect other adjustments. External circuits are connected to a terminal strip at the rear of the unit.

The curve of Fig. 8 shows an average response of "ultraviolet" prints on *EK-1301* for constant amplitude of mirror vibration. Negatives were on *EK-1357* and exposed through a 1-mm Corning 584 filter and the ultraviolet-corrected objective lens.

The advantages listed above which have heretofore been restricted to variable-density are with this modulator realized in variable-area. The laboratory model has been used for recording original soundtrack for several studio productions.

Though it is not possible to name all who have aided in this development we wish to acknowledge the contributions of Mr. R. Wolf and the coöperation of Mr. Foster of the Bausch & Lomb Optical Company.

#### DISCUSSION

MR. KELLOGG: Can you tell us more about the damping of the shutter and the galvanometer, and the manner in which the requisite stiffness is supplied to the galvanometer to give it a suitable natural frequency. It looks as if there were a tension spring across the window in which the mirror and armature are mounted, but I should be glad to have more details.

Also, I am interested in the reasons for using the large mirror and moving it farther from the slit. How does such an arrangement compare with a smaller mirror, closer up? I have always felt that the large mirror arrangement takes much more input. For the same amount of light modulation, there is more kinetic energy and that bears somewhat upon the power requirements, in which we are much interested; although I grant that more power than is at present supplied is not a great obstacle, if one benefits by it.

MR. BENFER: The armature is a torsional structure formed from a single piece of Permendur. It is separated from the pole-pieces by a tungsten wire on which it pivots. The mirror is cemented directly to the armature. Damping is obtained magnetically within the modulator itself and is controlled by selection in design, magnetic materials, and flux densities.

MR. LORANCE: Any device of this type has a response characteristic that is a function of the impedance out of which it is driven. The coupling network smooths out the impedance irregularities and provides equalization for the response characteristic. The impedance equalizer section is wasteful of power because resistance is put in series with the vibrator coil in order to simplify the network. About +28 to +29 db relative to 6 milliwatts is required at the network input for full modulation.

Damping is obtained chiefly through the design constants of the magnetic structure and is quite good as indicated by the relatively few free vibrations, or transients, accompanying a keyed signal.

The size of the mirror is related to the whole modulator by the optical working speed desired and by the magnifications or reductions involved. Practical considerations also have something to do with it. In the preliminary layouts of the modulator it appeared wise to use a rather large slit so that a rather large mask image would be available for observation in the plane of the slit, and so that components would be at distances that would not interfere with adjustment or observation.

MR. KREUZER: Has the exposure meter been corrected for temperature?

MR. LORANCE: No, it has not. It is included chiefly as a guide and as a check on lamp current. It is not a substitute for a lamp current meter.

MR. OFFENHAUSER: About what is the density of the slit in the opaque region?

MR. LORANCE: We have never tried to check it; but there has been no trace of useless light coming through. It is thick enough to be "opaque."

## DETERMINATION OF MICROPHONE PERFORMANCE\*

F. L. HOPPER AND F. F. ROMANOW\*\*

*Summary.*—Methods of determining the performance characteristics of microphones by acoustic measurements are described. Work Factors involving the accuracy of the methods are discussed. The correlation between a microphone's performance as determined by acoustic measurement and by listening tests is reported. Application of both types of test to a studio type of cardioid microphone is given as an example.

The performance characteristics of microphones are of considerable interest to studios since the ultimate sound quality of the recording system is a function of any limitations that the microphone may impose. Factors influencing the choice of a microphone for sound recording will not be considered here, since they have previously been described.<sup>1</sup>

Generally, two methods of judging a microphone's performance are available: listening tests and acoustic measurements.<sup>9</sup> Properly conducted listening tests can give considerable information regarding the microphone under actual conditions of use. Usually, comparisons are made between microphones of a known and used type, and others whose performance is unknown. The basic philosophy for such a test should be to determine which microphone gives the most faithful reproduction of the original speech or music. However, the performance of the new microphone is often contrasted with the results given by the old type, without reference to the original source of sound. Such a procedure is likely to be misleading. It would appear more straightforward to select the best microphone on a basis of comparison with the original sound-source, and then modify its performance characteristic, if necessary, acoustically or electrically, to secure the desired characteristic. This latter procedure may be justified at times due to other equipment limitations, or to a desire to achieve some particular type of sound quality for dramatic effect. Such listening tests for judging the microphone's performance are affected by stage

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\*\* Electrical Research Products, Inc., Hollywood, Calif.



acoustics as well as the characteristics of the associated transmission equipment, including recording or reproducing systems and the monitoring loud speaker. Inasmuch as this type of test represents the way in which a microphone is used, it is probably an effective way in which to judge actual performance.

Contrasted to this type of test is the determination of the microphone's response characteristics by means of acoustic measurements. Here the aim is, so far as possible, to remove all extraneous acoustical effects and characteristics of equipment. The resulting data show the inherent response of the microphone in a specific type of sound field. This type of test is particularly useful to the designer of microphones as a yardstick to judge his achievements.

If similar test equipments of comparable performance are available to the designer, manufacturer, and user, a common basis exists for a discussion of microphone problems. Similar test equipments, facilities, and technics are employed by Bell Telephone Laboratories and the Western Electric Company, and recently a comparable test set-up has been established at Electrical Research Products' West Coast laboratories. This system is available for the following purposes:

- (1) To serve as a reference. As such, it may be used to correlate and unify the results of various microphone test methods now employed by studios.
- (2) To determine the effects of acoustic baffles and wind screens, proposed or employed by studios, upon the normal characteristics of a given microphone.
- (3) To measure and compare the response characteristics of microphones of a given type and to check the performance of those suspected of trouble.
- (4) To correlate measured response with comments on a microphone's performance as judged from listening tests, leading perhaps to a better understanding of future design requirements.

The response of a microphone is defined as the ratio of the open-circuit voltage generated at the terminals of the instrument to the acoustic pressure actuating the device. Two methods of measurement are generally available. In the first, or "pressure" calibration, the pressure is uniform over the diaphragm and is measured at the diaphragm. In the second method, or "field" calibration, the microphone is introduced into the field of a plane progressive sound-wave. The presence of the microphone distorts the sound field, and the pressure on the diaphragm of the microphone is different from that existing before the microphone was placed into the field, due to diffraction and resonance effects around the microphone. In the "field" calibration of the microphone the undisturbed sound pressure,



that is, the pressure before the microphone is placed into the sound field, is taken as the input pressure. The field response of a microphone is, therefore, the open-circuit voltage divided by the undisturbed sound pressure at the microphone position.

An example of a "pressure" calibration is illustrated by the thermophone method<sup>8</sup> of calibrating condenser transmitters. It is primarily useful in establishing the characteristics of a condenser transmitter that may subsequently be used in making field calibrations of other microphones. In this method, the diaphragm of the transmitter constitutes one wall of a small cylindrical enclosure. Inside this chamber are mounted two strips of gold foil through which alternating and direct currents are passed. The cyclic changes in the alternating current produce corresponding changes in the temperature of the foil, and therefore an alternating pressure distributed uniformly in the chamber is created to actuate the transmitter diaphragm. In order to prevent resonances from occurring in the chamber at frequencies at which the pressure calibration is made, it is filled with hydrogen gas, which displaces such irregularities upward in the frequency range.

Since the field calibration method more nearly corresponds to the performance of a microphone under conditions of use, it is of more general interest. A field calibration of a commercial type microphone is generally made by a comparison method. A reference microphone whose field characteristic has been established by basic methods is introduced into a sound field. Its output may be measured and drawn automatically by means of a sound-level recorder. The unknown microphone is then similarly measured in the same sound field and the difference in response is applied to the field calibration of the known microphone, thus determining the field calibration of the unknown microphone.

A number of precautions must be taken if accuracy is to be achieved. A fundamental requirement is the provision of a stable calibrated reference microphone. The miniature condenser transmitter 640-A probably represents the best obtainable microphone for this purpose. An exact field calibration of the miniature transmitter is necessary. This is done by using a field of a plane progressive sound-wave and measuring its pressure by means of a Rayleigh disk.<sup>2</sup> Briefly, this method depends upon the fact that a light disk suspended in a sound field tends to orient itself so that its plane is perpendicular to the particle displacement in the wave. Data obtained from such a device permit a mathematical calculation of the sound-field pressure to

be made. A measurement of the output of the condenser transmitter when placed in this known sound field then gives the data for its field response. This calibration, when compared to a pressure calibration of the same transmitter by the thermophone method, shows a marked increase in the output at the upper frequency range. The increase is caused by two factors: (1) the diffraction caused by the microphone, and (2) the resonance of the small cavity in front of the diaphragm. The diffraction effect of a circular disk has been given in a recent paper<sup>3</sup> and is shown in Fig. 1. To this must be added the resonance effect due to the small cavity in front of the diaphragm which can be calculated.<sup>4</sup> The sum of these two corrections is added to the ther-

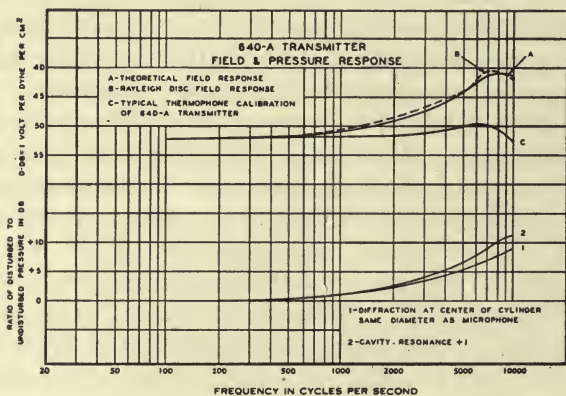


FIG. 1. Diffraction effect of a circular disk.

mophone calibration of the 640-A transmitter to give the theoretical field response. Fig. 1 compares this response with the Rayleigh disk calibration, and it is found that good agreement exists between the two methods of arriving at the field calibration. The difference between field and thermophone response, sometimes referred to as a field correction is a constant for this type of microphone, since the effect is a function of the physical shape and size alone and does not depend upon the electrical properties of the transmitter. Since a Rayleigh disk calibration is laborious and time consuming, and subject to disturbances by extremely light air currents in the testing room, it is more practicable to calibrate the individual miniature transmitters with the thermophone and to apply the field correction previously determined for this type.

In using miniature condenser transmitters an electrical correction is also required. A condenser transmitter with small active capacity experiences a coupling loss when connected to an input circuit of a vacuum tube. To measure this effect, a voltage is placed in series with the microphone and the output voltage is observed. Then the transmitter is disconnected, and the same voltage as before is applied to the input terminals of the system. The output voltage is observed again. The difference between the two output voltages in db is the



FIG. 2. Sound-treated room of the Bell Telephone Laboratories.

coupling loss, and is a measure of the voltage generated at the grid of the tube by the transmitter as compared to its open-circuit voltage. This correction is necessary since in calibrating microphones it is customary to compare the voltage which an unknown microphone generates at the grid with that of the reference microphone also at the grid. If the unknown microphone is of sufficiently high impedance compared to the input impedance of the test amplifier, a similar procedure is necessary to obtain its open-circuit voltage, which is the quantity needed for stating the response. Periodic checks of the condenser transmitter by the thermophone method, and an electrical check of



the amplifier circuit into which it operates insures detection of any change in the standard.

It is obvious that if the sound field into which the microphone is placed is non-uniform, errors will be introduced due to an inability to separate distortions produced in the sound field by the microphone from those inherent in the field itself. Disturbances in the sound field around the microphone that are not due to the microphone itself

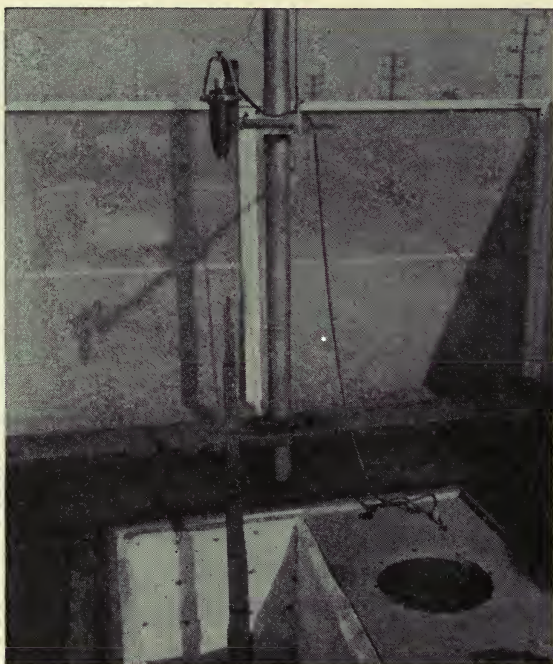


FIG. 3. Outdoor set-up

are those due to reflections from surrounding surfaces. Most of these effects may be minimized by utilizing sound sources that radiate principally in one direction, thus limiting reflections to one principal surface, by utilizing a room so constructed as to be nearly completely absorbing,<sup>5</sup> or by working outdoors. When weather and noise conditions are severe, use may be made of the sound-treated room. Such a room in use at the Bell Telephone Laboratories is shown in Fig. 2. However, favorable outdoor conditions in Hollywood led to a decision to establish a measuring set-up outdoors; as a consequence, the loud



speakers were installed in the roof of the ERPI Laboratory, pointing vertically upward, with a boom structure provided to support the microphone above the loud speakers. A wind screen, cheesecloth on frames, surrounds the structure and permits measurements to be made under varying conditions of wind. The wind screen is sufficiently remote and transparent acoustically to cause a negligible effect upon the sound-field characteristic. This set-up is such that it permits calibrations to be made of microphones at varying degrees of incidence. With highly directional microphones, the response may decrease some 20 to 30 db for certain angles of incidence. The arrangement mentioned, shown in Fig. 3, permits this to be done.

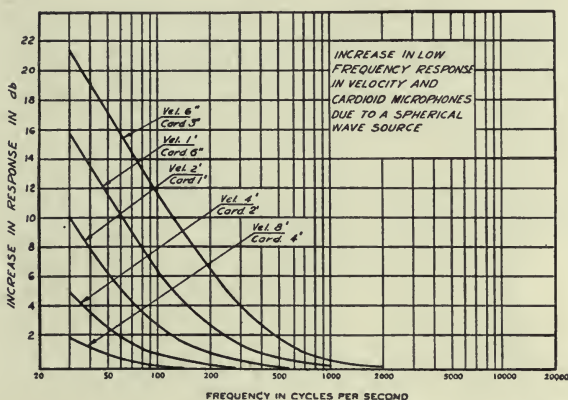


FIG. 4. Correction for ribbon and cardioid types of microphones.

Due to the method of comparing two microphones, the sending and receiving links of the measuring system are common to both sets of measurements and in general may be disregarded. Under some circumstances, when deriving the response characteristic of one type of microphone from that of an entirely different type, certain corrections are necessary. Among these are:

(1) Corrections due to a difference in performance when microphones of different types are operated into an input transformer in the measuring system. This might be due to a difference in impedance characteristic as a function of frequency with which the input transformer is faced; or, in the case of microphones employing output transformers, some reaction between the latter and the input transformer of the measuring system. Since it is customary to describe a microphone-response characteristic in terms of open-circuit voltage, it should either be measured with the microphone connected to the grid of a vacuum tube, or, when oper-

ating into a transformer, the effects of the transformer should be determined and removed from the measurement. Such corrections are usually required in the case of cardioid and ribbon microphones.

In general, when comparing the output obtainable from two electrodynamic microphones, it is necessary to consider their impedances. Suppose two microphones have the same field response but one has a 10-ohm impedance and the other a 1000-ohm impedance. We might connect an ideal transformer to the terminals of the low-impedance microphone to bring it up to the 1000-ohm impedance level. This would increase the voltage output of the 10-ohm instrument by 20 db. Since the open-circuit voltages were equal without the transformer, the

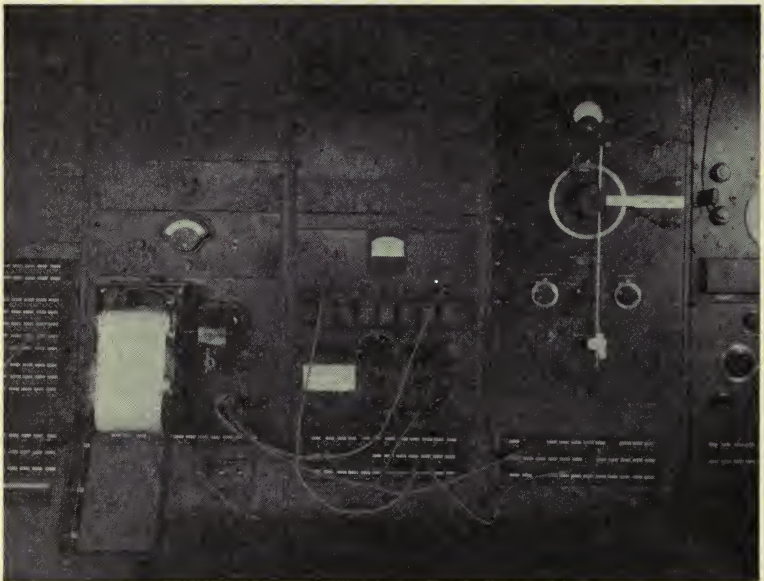


FIG. 5. Equipment in room below the loud speakers.

output of the 10-ohm microphone can be increased 20 db. It is apparent from this example that a statement of the field response of a microphone is incomplete as an indication of the obtainable voltage output unless its impedance is also mentioned.

(2) When measuring at low frequencies with microphones operating wholly or partially upon a pressure-gradient<sup>9</sup> basis, a correction must be made due to the increase in amplitude and phase-shift of the particle velocity relative to pressure. Were the sound radiator capable of supplying a plane wave, this would not be necessary; but with the usual types of loud speaker and the close distances at which measurements are made, the wave-form is approximately spherical and a correction is required. The nature and magnitude of this correction for ribbon-

and cardioid-type microphones are shown in Fig. 4. For example, if a ribbon microphone is 6 inches away from a spherical sound-source its output is increased by 11.5 db at 100 cycles over that with a plane-wave source. For the same increase a cardioid microphone would have to be nearer the sound-source, namely, 3 inches away.

Actual measuring equipments, while varying in detail, generally operate in much the same manner. The following brief description covers the ERPI test equipment utilized in Hollywood. As has been mentioned, the loud speakers and microphones are located on the roof of the Laboratory with measuring equipment located in a room below. The loud speaker system consists of a low-frequency dynamic-type unit utilized for frequencies from 50 to 500 cycles. A moving-coil type of receiver unit is coupled to an acoustic impedance element (tubular microphone) and is utilized as a radiator for frequencies from 500 to 10,000 cycles. In this instance the tubular structure is employed as a directional radiator of sound rather than in its usual role as a sound collector. Its advantages are two-fold: it radiates directionally, thereby reducing reflections from nearby objects, and it provides a sound field of very uniform character, in one direction. Generally, the pressure at any point in the sound field in the vicinity of the microphone test position does not deviate more than 1 db from an average value.

The remainder of the equipment is located in the room beneath the loud speakers and the principal components are shown in Fig. 5. A beat-frequency oscillator equipped with a motor-driven sweep supplies frequencies to a power amplifier, volume indicator, and the loud speakers. The standard or unknown microphone's output is applied to a two-stage amplifier. This amplifier is designed to operate directly from a microphone, or from a microphone and associated amplifier, as in the case of the condenser transmitter. The amplifier operates directly a volume indicator having a logarithmic response characteristic, *i. e.*, its deflections are linear in db. The output current of the volume indicator supplies a d-c recording type of milliammeter. Combined with the sweep features of the oscillator is a contacting device which marks the position of a number of frequencies upon the recorder chart through the use of an auxiliary pen located in the margin of the chart. The system is automatic in its operation. The response characteristics of the loud speakers are sufficiently uniform so that an inspection of the chart gives a rough approximation of the microphone response characteristic. Sufficient



sound energy output can be secured from the loud speakers so that the signal-to-random-noise ratio at the microphone does not limit measurements of 90- or 180-degree response in pressure gradient of cardioid microphones.

Utilizing a calibrated, miniature-condenser transmitter and the described system, response characteristics have been derived for a number of different types of microphones that had been previously calibrated by similar methods at the Bell Telephone Laboratories. The results of these two calibrations on the average agree within 1 db, with occasional maximum disagreements of the order of 2 db. This agreement is considered excellent for this type of measurement.

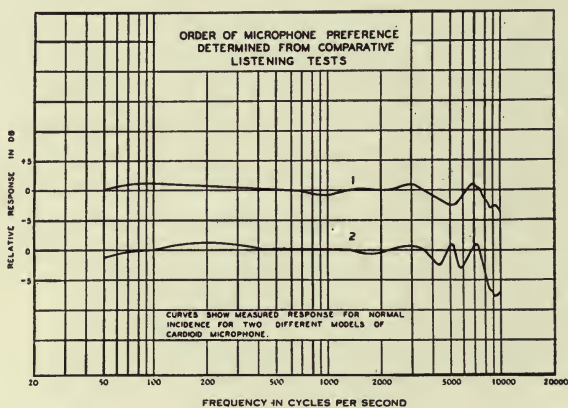


FIG. 6. Normal incidence response characteristic for the cardioid condition.

Having discussed methods of determining a microphone's characteristic by acoustic measurement, it is of interest to relate how the data correlate with those obtained from listening tests utilizing speech and music as a sound-source. The differences in response characteristics of two microphones having different relative amounts of low or high frequencies are easily detected by ear. These differences agree with the results of acoustic measurement. However, in many instances two microphones of the same type may have nearly, or the same, proportion of low to high frequencies, so that it might be expected that they would sound alike. It is common experience that such microphones may still exhibit noticeable difference in sound quality. The difference is often described in terms of smoothness, naturalness, or definition. It is apparently a function of the number and amplitude



of the sharp irregularities that occur in most microphone response characteristics. A reduction in either of these factors results in an improvement in quality that the ear can appreciate. As a check, listening tests have been conducted with a number of microphones of a given type, the microphones being rated as to order of preference. Acoustic measurements were then made and it was found that the best instruments were those that had the smallest irregularities in their response characteristic. Thus acoustic measurements become a

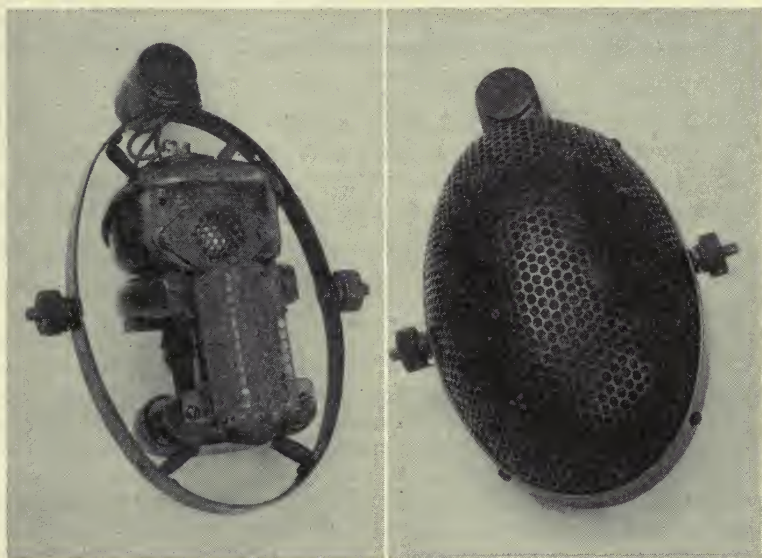


FIG. 7. Two views of the microphone.

more valuable tool in evaluating performance of microphones under design before they reach the field.

Such factors have been given consideration in the design of a cardioid type of microphone designed primarily for use in motion picture sound recording. The cardioid characteristic is obtained by combining in series the outputs of a pressure-type element and pressure-gradient element.<sup>6</sup> While the cardioid characteristic is obtained when equal voltages are supplied by both elements, other useful directional patterns may be secured by varying the proportionality of voltages taken from the two units.<sup>7</sup> This variable directional pattern is useful in three-walled or enclosed sets. A certain amount of

reflected sound may be excluded by the choice of one of the various patterns, with a definite improvement in quality. This is particularly noticeable in the bass register. In this way the new microphone accomplishes an effect acoustically that can not be readily achieved by electrical equalization in the recording system.

The normal incidence response characteristic for the cardioid condition is shown by the upper curve of Fig. 6. For the purpose of a listening test, a microphone having such a response was compared with a laboratory model that had a somewhat abnormal characteristic, as indicated by the lower curve of Fig. 6. It was found that the ear could recognize a quality improvement corresponding to the reduction in irregularity of response. The shape of the microphone housing was designed with this in mind. Its symmetry of shape and the silk screen cemented to the housing aided in minimizing wind noise. The microphone is illustrated in Fig. 7. The resilient mounting of the microphone unit within the housing makes the instrument less susceptible to mechanical movement when it is used on a microphone boom or fishpole.

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#### DISCUSSION

MR. DAILY: Has a correlation been worked out yet between the measured rate of change of the response characteristic of a microphone in the region of irregularities and the accompanying quality deterioration that takes place?

MR. HOPPER: I believe not. We have recognized only recently that these irregularities can be appreciated by the ear. At the present time I do not believe we are in a position to describe accurately what sort of irregularity produces a given effect.

MR. LINDSAY: Is the sound-source always warbled in this test?

MR. HOPPER: No. Measurements were made using a warble only, a sweep only, and a combination of both. We found, due to the fairly uniform sound field we had, and the absence of surfaces surrounding the sound field, that the sweep was quite adequate.

MR. TASKER: Will you kindly explain in detail the set-up shown in Fig. 3?

MR. HOPPER: Fig. 3 shows the pipe structure. The microphone is supported by the boom arm at a fixed distance from the longest pipe. The sound field at this point was explored with the condenser transmitter for uniformity, and found to be satisfactory. In high-frequency response measurements the plane of the microphone diaphragm is placed at a specified distance from the end of the longest pipe. For measurements at various angles of incidence the microphone is rotated about a horizontal axis, keeping the center of the diaphragm above the longest pipe. For measurements at low frequencies the microphone is centered over the low-frequency loud speaker by rotating the boom arm. The pipe structure is acoustically coupled to an electrodynamic type of driving unit.

MEMBER: The curves you showed were for horizontal response; what about the response in a vertical plane?

MR. HOPPER: They are almost identical. If the cardioid pattern is rotated so as to describe a complete solid, the characteristics in the horizontal and vertical planes will be nearly the same.

MEMBER: Would there be any difference in response if the microphone were suspended so that the unit would hang vertically?

MR. HOPPER: The position of the microphone is probably limited by the way it is used in production. Microphones are generally hung from a boom or fish-pole, and are overhead to get them out of the camera line. That necessitates pointing them down at the actors. There is not much occasion to use them in other ways.

MR. TASKER: The question may have to do with a phenomenon that has been commented on from time to time. It has been said that a velocity-type microphone, if tilted in one direction or another while following the actors, may become "bassy." That may not be true, but it has been claimed.

MR. HOPPER: The ribbon element in this microphone is constructed in such a way that, while it is rather rigid, it may still move freely in the magnetic field under the influence of an acoustic wave. It is our belief that the response characteristic of the ribbon is independent of its operating position.

MR. RYDER: Have any measurements been made to determine the effect, upon the measurements, of two frequencies imposed upon the microphone at the same time?

MR. HOPPER: Not in that particular way, although we inadvertently made measurements with sufficient input to the loud speaker to cause overloading. There were many harmonics in the output, but the measured response of the microphone was the same.

MR. RYDER: Has the system been used for calibrating microphones? Is there



any difference between measurements made outside in summer or winter, or under low or high humidity?

MR. HOPPER: This much has been noted: the pipe structure that is used as a high-frequency sound-source is somewhat subject to frequency characteristic changes with humidity. In other words, the response of the device as a loud speaker does vary somewhat with temperature and humidity. Since the calibrated condenser retains its calibration, it is possible by that means to determine whether the speaker system changes.

The only time such an effect is of consequence is when the speaker system changes while the measurements are being made. If the system remains stable for the two comparison measurements, that is all that is required. If we make measurements over the course of a day, check runs are made with our calibrated microphone at sufficient intervals to assure ourselves that the loud-speaker system has not changed, or, if it has, to enable a correction to be applied.

MR. SKINNER: How long does it take to make a measurement of a unit?

MR. HOPPER: About fifteen minutes to set the equipment up and about a minute and a half to make one run. Two runs are required, one on the calibrated microphone and one on the unknown microphone. It is done with a continuous sweep, and it is recorded by a continuous chart recorder, so it is completely automatic in its operation.

MR. SKINNER: Could you not speed it up?

MR. HOPPER: If the sound field is shifted too rapidly some of the irregularities in the response of the microphone will not appear on the chart. There is a definite time interval below which one should not go in order to get a true picture of what the microphone is doing.

DR. DAILY: The charting-type meters used in the measurement of response characteristics have definite time-deflection characteristics, approaching one second for one type in common use. Therefore, if rapid variations in amplitude occur, due to irregularities in response of the microphone under test, the needle of the meter will not truly follow the change, resulting in an inaccurate charting of the characteristic.

MR. MUEHLER: What is the amount of distortion in this or any other type of microphone?

MR. HOPPER: We have not been successful in making such measurements. Usually the harmonic output of the loud-speaker system is a "bottleneck," and as a result the measurements do not mean anything.

Once we tried measurements supplying square waves to the loud-speaker system but that was unsuccessful. All the harmonics of the square wave must be reproduced in the proper phase to get the square waves back. Since the loud speaker will not do that the resultant patterns did not mean anything. I doubt very much whether the harmonic output of the microphone is a very appreciable factor.

MR. LINDSAY: Can you tell us something about the frequency range of these later-type microphones?

MR. HOPPER: The cardioid microphone was designed to be usable up to 15,000 cycles with moderate equalization. The response curve is quite uniform up to about 8000 or 9000 cycles, requiring about 6 db of equalization to flatten it out at 15,000 cps. It was intended to be used with the stereophonic equipment, where we strive for a wider frequency band.



## SCENE-SLATING ATTACHMENT FOR MOTION PICTURE CAMERAS\*

F. C. GILBERT\*\*

*Summary.*—The anticipated reduction of film markets attendant upon disturbances in Europe caused many studios to reexamine production routines and practices with a view to reducing costs without impairing quality.

A routine, in widespread use in much the same manner, which gave promise of cost saving was that of marking "takes," at time of photographing, for ready identification through subsequent stages of picture production. The process of so marking film is referred to, within the studios generally, as "slating."

Analysis of the shortcomings of the slating method employed by our studio led to the development of a slating attachment mounted upon the camera blimp or iris rods and operated by the assistant cameraman.

The design requirements formulated and the manner and degree of compliance embodied in the device now in production use are described.

The anticipated reduction of film markets attendant upon the disturbances in Europe has caused many studios to reexamine production routines and practices with a view to reducing waste.

A routine in widespread use that gave promise of cost saving was that of marking "takes," at time of photographing, for ready identification through subsequent stages of picture production. The process of so marking film is referred to within the studios generally as "slating."

The scene-slating method in use heretofore at Paramount has required that the assistant cameraman carry out onto the set a slate-board some 14 inches high by 12 inches wide bearing the identifying legend. In general, the scene and take numbers consisted of printed inserts slid into holders provided on the slate. Such other information as might be desired was written or printed upon insert strips for which, also, holders were provided on the slate. It was the practice to run the camera "wild" from rest to photograph the slate between the end of one take and the beginning of the next. The camera was

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\* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received October 31, 1940.

\*\* Paramount Pictures, Inc., Hollywood, Calif.

then stopped, restored to the interlock system, interlocked, and the start-mark fogged onto the film, whereupon the camera was ready to be restarted upon call. The camera, recorder, and, where involved, the background projector, start in interlock. Through the automatic operation of a douser in the recorder, sound-track exposure begins at the instant the interlocked system starts turning over, thereby providing the necessary sound-track synchronizing information.

The practice of scene-slating between takes rather than upon starting in interlock was adopted to eliminate the distraction caused by the assistant's running out onto the set and holding up the slate, often literally under the noses of the actors. However, the "between takes" slating practice is subject to three serious objections: (1) it consumes film not otherwise required; (2) where a retake follows immediately upon the conclusion of the preceding take there is a loss in production time wholly assignable to slating; and (3) frequently there occurs both time loss and waste of footage over the period required for the assistant to move out of the field of the camera.

The scene-slating procedure, when the attachment to be described is used, is as follows: The camera stands "ready," having been interlocked and the start-mark fogged. Upon the order to "turn-over" the assistant cameraman presses a lever raising an auxiliary optical system to a position on the camera's optical axis and immediately in front of the camera or blimp, thereby exposing the film to the slate while the motor system is coming up to speed. At the instant the signal is received, indicating that the motor system is up to speed, the assistant cameraman removes his finger from the slater-operating lever, permitting the arm carrying the auxiliary optical system to drop back into the slater housing whereupon "action" can commence.

Assuming that the new procedure, for 50,000 takes per year, saves only the cost of  $3\frac{1}{2}$  feet of developed negative per slate, together with the cost of developed prints for the slates actually printed and developed, the new system gives promise of a potential annual reduction in film expense of \$8000. This figure does not attempt to evaluate production time saving or time saving accruing elsewhere throughout the various operating phases as a result of the improvement in the legibility of the average slate.

At the outset of the design of the attachment the following requirements were established as necessary or desirable:

- (1) That the device be adaptable to the following types of camera equipment:  
Mitchell NC Camera

in blimp,  
on open tripod,  
boom mounted.

Mitchell Standard Camera

in booth,  
on open tripod.

Bell & Howell Camera

(2) That the slating attachments be interchangeable.

(3) That the device provide legible complete slates for camera lens focus distance settings from 6 feet to infinity when used with lenses of the focal lengths commonly employed.

(4) That a range of illumination adjustment be provided to accommodate stop settings between  $f/2.3$  and  $f/22$ .

(5) That the scene and take numbers as well as other data subject to change on each take be determinable at any time by the assistant from inspection of the exterior of the device.



FIG. 1. Slating attachment and battery box.

(6) That the device be usable on location as well as throughout the studio.

(7) That the device fall of its own accord out of the range of the camera upon completion of the slating operation.

(8) That weight and bulk be minimized.

Fig. 1 shows the battery box and the slating attachment in its closed position. The mounting brackets, which are attachments permanently associated with each of the blimps and cameras of the several types, are not shown. Any of the sixteen slating attachments manufactured may be used on any of the twenty-nine blimps, booths, or cameras of the types mentioned above and now equipped with the requisite standardized mounting facilities. The lack of uniformity between cameras or blimps of a given type has been accommodated in the fabrication of the brackets referred to.

Battery power supply to operate the lamps used to illuminate the slate face was selected in preference to power taken from the motor power supply circuit because of the complications arising from the



fact that the motor power supply might be 220-volt a-c, or 32-volt, or 135-volt d-c, depending upon the particular camera set-up in use.

Fig. 2 shows schematically the optical layout of the device. The face of the slate-box is illuminated by four bulbs located two on each side of the slate. Proceeding from the slate face in the direction indicated by the arrow the image of the slate is reflected up by a second-surface mirror, through the first of two focus-correcting lenses onto a first-surface mirror located on the optical axis of the camera; thence through the second focus-correcting lens and through the camera lens, imaging the slate at the plane of the film.

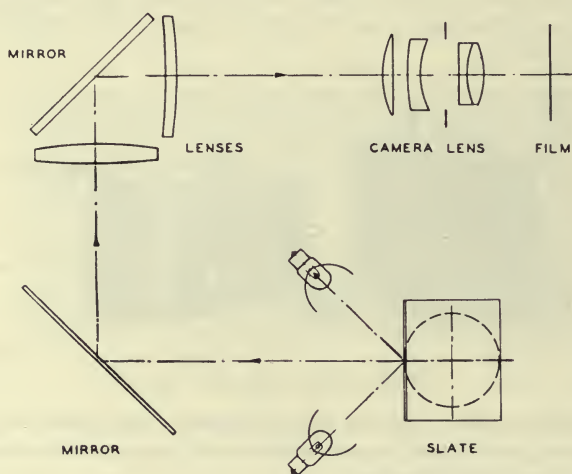


FIG. 2. Schematic of optical system.

A second-surface mirror was used adjacent to the slate because of the impracticability, due to its location, of enclosing the mirror in a protective housing. The first-surface mirror and the two focus-correcting lenses are combined in a dustproof sub-assembly.

The focus-correcting lens system was calculated to provide the best focus of the slate when the camera lens in use is focused upon a plane 8 feet 6 inches from the camera. Due to the limited depth of field of any lens system this distance, necessarily a compromise, was chosen with a view to securing legible slates over the range covering the largest possible number of normal shots. Because of the low curvature of the focus-correcting lenses, it was not necessary to cor-



rect them chromatically. The curves used were chosen to minimize spherical aberration.

A further necessary consideration was the size of the slate-box face. Since the focal distances were established rather closely by mechanical considerations, it was necessary to limit the slate face to a size such that for the longest focal length lens normally used the image produced at the film plane would not be so large as to result in cutting off essential printed matter. At the same time it was desirable to keep the slate face as large as possible, to the end that with the shortest focal length lens the best image legibility might be maintained.



FIG. 3. Slates obtained for indicated photographic conditions.

It is our belief that it is more important to avoid the possibility that even an occasional scene may be photographed out of focus through failure of the assistant properly to reset the camera lens than it is to insure, by separate focusing for the slate, that all slates be in more perfect focus. Our operating practice as regards the slate is based on that premise but may be changed if desired.

Fig. 3 shows that without refocusing the camera lens good slate legibility is maintained for the 35-mm lens for focus adjustments of the lens between 5.5 feet and 40 feet when operating at  $f/2.3$ . The legend on the white inserts describes the conditions as to stop setting, and distance for which the focus of the lens was set.

For camera lenses of focal lengths longer than 35 mm when operating at  $f/2.3$ , the out-of-focus condition of the slate image impairs legibility for camera lens focus distances less than  $5\frac{1}{2}$  feet and greater than 35 feet.

For all focal length lenses between and including 24 mm and 100 mm slate size is satisfactory. Legibility as far as focus is concerned

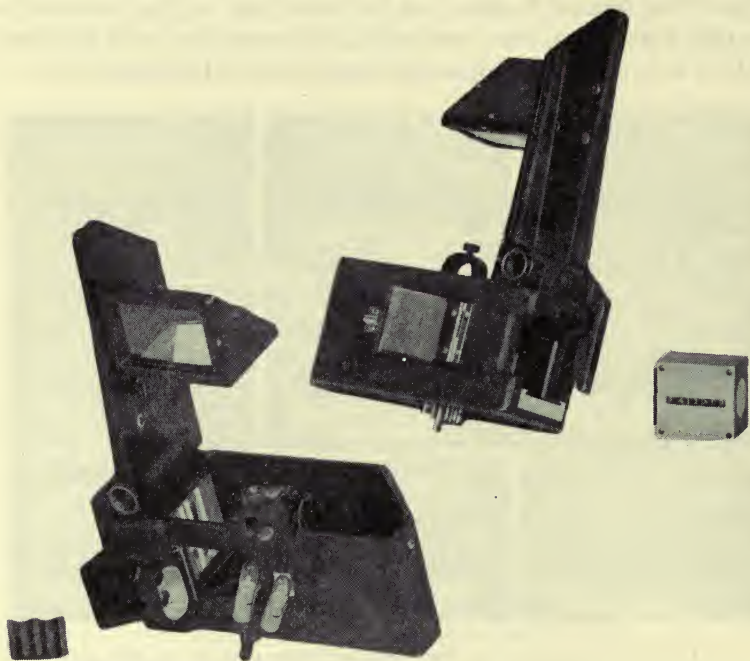


FIG. 4. (*Upper*) Front view of attachment showing operating arm blocked in its "raised" position and slate-box removed.

FIG. 5. (*Lower*) Attachment with slate-box inserted, arm "raised" and one of the lamp housings swung open and lamps dismounted.

is satisfactory for lens focus distances from 4 feet to infinity provided the stop is  $f/4.5$  or above.

The seriousness of the limitation on the longer focus distances is alleviated in practice by the fact that most of the takes involving adjustment of the camera lens to distances of 35 feet or more are out-of-doors where the use of stop settings of  $f/8$  or higher removes the limitation.

Fig. 4 shows the attachment with the slate-box removed and with the operating lever carrying the auxiliary optical system blocked in its "raised" position. The hinged cover on the front surface of the attachment housing carries two of the  $2\frac{1}{2}$ -volt,  $\frac{1}{2}$ -ampere bulbs which illuminate the slate-box face. The housing attached at the top of the vertical arm carries the sub-assembly consisting of the first-surface mirror and the two focus-correcting lenses.

Fig. 5 shows the attachment with the operating lever in its raised position and with one of the lamp covers swung open to show the ease of bulb replacement. The bulbs in their sockets are shown removed from their reflector, which is integral with the lamp cover casting. The separate piece shown to the left is the clamping plate which holds the bulbs and their bayonet sockets in position. It is held in place by a thumbscrew. The face of the slate-box may be seen at the end of the housing.

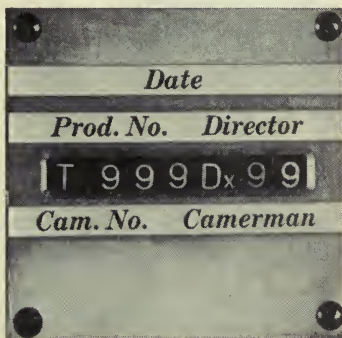


FIG. 6. View of slate-box face indicating information carried thereon.

Fig. 6 shows the slate-box face. The white characters on the black background are on manually operated, numbered wheels which are adjusted to show the scene and take numbers. The first wheel is provided with letters to identify the following special types of takes:

<i>E,</i>	Special Effect
<i>R,</i>	Retake
<i>T,</i>	Transparency (Process)
<i>Z,</i>	Test

This first wheel contains also the digits *1, 2, 3, etc.*, which permit setting up scene numbers as high as 3999 should such a necessity arise. The next three wheels each carry the numbers *0* to *9*, plus blanks, and constitute the scene numbers.

The fifth wheel bears the following notations:

<i>X,</i>	Sync (wild motor) Shot
<i>A, B, C, D,</i>	Camera Angles
<i>Ax, Bx, Cx, Dx,</i>	Sync Shots from Indicated Angles



The remaining two wheels carry numbers from 0 to 9 plus blanks, and are used to number takes. Thus the figure as shown in Fig. 6 represents Scene No. 999, which is a transparency set-up, take No. 99, made without sound (sync), and from camera angle *D*.



FIG. 7. Battery-box.

In order to provide a degree of flexibility as to the information carried by the slate, three removable, white, matte Vinylite strips are provided upon which notations may be made in pencil or printed. The information normally required in addition to that provided by the numbered wheels is as described on the white inserts of Fig. 6.

The slate-box with all data may be removed readily from the slating attachment housing for the insertion of new slips, or for alteration of the date. It is not necessary to remove the slate-box to set scene

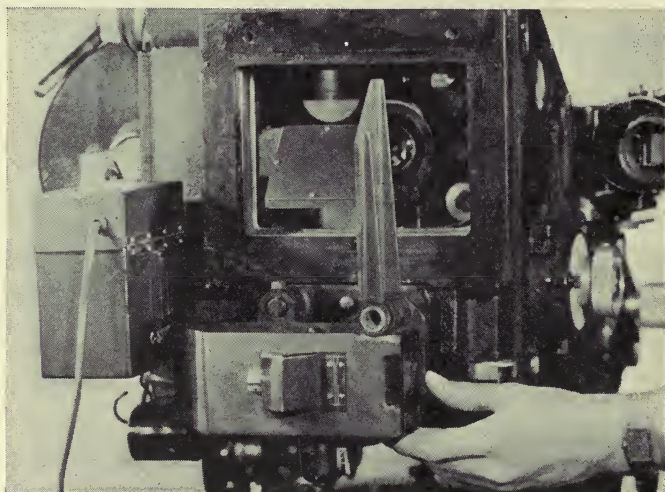


FIG. 8. Attachment and battery-box shown mounted on NC blimp (sunshade removed).

and take numbers. The seven numbered wheels extend through the rear of the slate-box and carry a second set of numbers visible to the operator at all times and indicating the corresponding data appearing on the slate face.



Fig. 7 shows the battery-box. It weighs  $5\frac{1}{2}$  pounds and is 6 inches long, 3 inches wide, and  $6\frac{3}{4}$  inches high. The three-position selector switch located beneath the strap handle adjusts the slate illumination. The switch plate is marked in three steps " $f/2.3-4$ ," " $f/4-8$ ," and " $f/8-16$ ." The switch is set to include the lens stop in use for a particular take. On the setting including  $f/16$  satisfactory exposure is obtained for a stop of  $f/22$  although a condition of under-exposure is being approached for certain picture printing conditions.

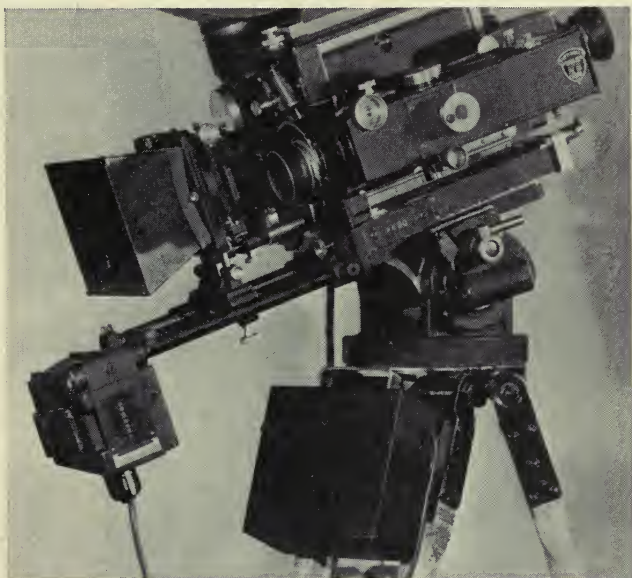


FIG. 9. Attachment shown mounted on open tripod set-up of NC camera.

The batteries used are of the 6-volt radio *A*-battery type connected in parallel. The battery capacity has proved adequate for from two to three months' service in normal use on studio sets.

Fig. 8 shows the attachment and battery-box mounted upon the NC camera blimp, in the operating position. The sunshade has been removed from the blimp to afford a better view of the slater.

As the attachment arm reaches its stop, the arm actuates a micro-switch connecting the power supply to the bulbs which illuminate the slate face. When the operator removes his thumb from the operating lever, the arm swings down of its own weight into the at-

tachment housing and the switch opens, turning off the lights. The arm is made so as to furnish a reasonably dustproof cover for the housing.

The batteries are connected to the attachment by a cable and plug. The plug is equipped with a latch which must be released by hand before the plug can be separated from the attachment. A second latch, released by the insertion of the connecting plug, locks the slater arm in its closed position, thereby preventing slating unless the battery connection has been made.



FIG. 10. Slater-equipped *NC* camera, on boom.

The sunshade has a slot in its bottom surface through which the slater arm is raised into its operating position.

Fig. 9 shows the attachment in its closed position mounted upon an open tripod or "sync" set-up of the Mitchell *NC* camera. It affords a view of the knurled wheels and tell-tale numbers on the rear face of the slate-box. When the 100-mm camera lens is employed in this sync set-up, it is necessary to operate with the sunshade removed.

Fig. 10 shows the slater in use on an open Mitchell *NC* camera in the air on one of our large booms in which situation its ad-

vantages are obvious. Where the old slating method was employed such situations resulted in slate images so small as to require the use of a magnifier or projection of the picture to identify the take. Additional camera situations, many encountered in daily practice, where the slating attachment is a distinct advantage, will undoubtedly suggest themselves to those familiar with the various phases of motion picture photography.

The first slater of this type was placed on field trial in production use early in January, 1940. All cameras in use on the lot and on location are now equipped with the attachment as described. After several months of such general use we find the device and the slates it produces popular with the various technicians whose work required their use.

## A MONOCHROMATIC VARIABLE-DENSITY RECORDING SYSTEM \*

O. L. DUPY AND JOHN K. HILLIARD\*\*

*Summary.*—This work was undertaken to determine the benefits of a true monochromatic optical system for variable-density recording in the ultraviolet region. A full quartz optical system consisting of both spherical and cylindrical lenses was used, having a reduction of 10–1 from the light-valve spacing. The reduction in lens distortion and improvement in general image quality is reported along with intermodulation tests on the system, which uses an automatic air-controlled mercury-vapor lamp system.

Much emphasis has been placed on the necessity of reducing modulation products in a film-recording system. Previously reported analyses indicated the advantage to be obtained by reduction of the effective height of the image in variable-density recording with a light-valve.

Fig. 1 shows the computed intermodulation due to ribbon velocity effect when 60 cycles and a higher frequency are recorded simultaneously on the film with a 12-db differential between the two frequencies.<sup>1</sup> From these data it will be noted that the height of the image on the film should never be greater than 0.25 mil, and it is preferable to reduce the image still more.

Originally the light-valve ribbons were spaced 2 mils apart, using a 2 to 1 optical reduction on the film; very soon after this, the spacing was reduced to 1 mil. This reduced the effect of high-frequency loss and intermodulation considerably, but the need of further improvement was recognized.

Several years ago, in an effort to make a variable-intensity system, a double quartz wedge was inserted between the light-valve and the film so that the variable width of the light-valve was changed into variable-intensity at the film. This system reduced the intermodulation at high frequencies to a very low degree, but its commercial application was retarded due to its poor light efficiency. Later, a 4 to

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\* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received November 19, 1940.

\*\* Metro-Goldwyn-Mayer Pictures, Culver City, Calif.



1 optical system was made available such that a 0.25-mil image of a 1-mil light-valve was set up on the film with approximately 50 per cent loss of light. This system is now in general use today in practically all release recording machines and in a great number of original negative production machines.

However, due to the fact that the current standard practice uses 1.5 to 2-mil movements of the ribbons, the image on the film is as

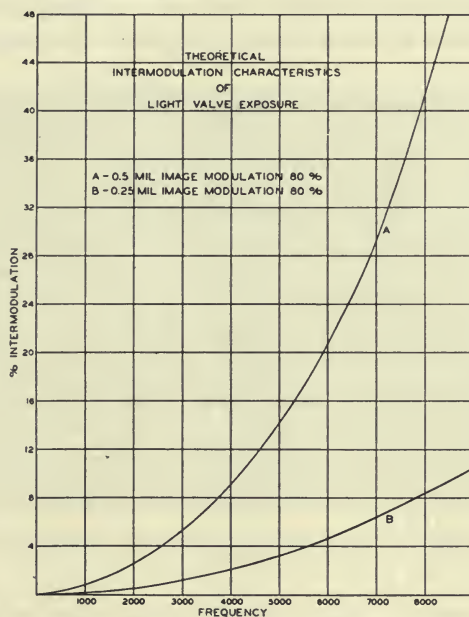


FIG. 1. Computed intermodulation due to ribbon velocity effect.

great as 0.5 mil. This image width at high levels produces comparatively high intermodulation products and the need of reducing these products still more is very desirable.

Improvements due to further correction of spherical and chromatic aberration in recording optical systems has indicated the need for the reduction of this type of distortion to a minimum. It has been felt that a true monochromatic lens system in which a nearer approximation to variable-intensity could be accomplished would remove to a minimum all the distortions pointed out above.

The improvement and practical application of the mercury arc as a source of illumination for variable-density recording encouraged the development of the monochromatic system, since a light-intensity many times that which could be obtained from the incandescent lamp is available in the spectral band desired.

Previously published work has shown the bad flare on ordinary positive stock when exposed with incandescent light at both high and medium low frequencies due to scattering within the emulsion and due to reflection from the back surface of the base into the emulsion. The use of filtered light, or the mercury arc, as a source materially

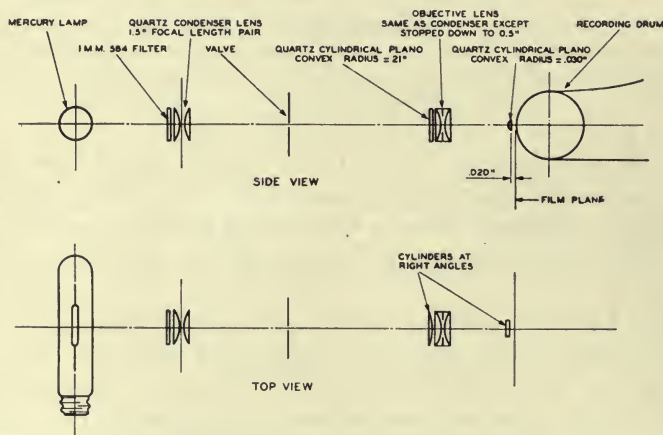


FIG. 2. Monochromatic optical system for variable-density recording.

reduces these effects. This is due to the fact that the absorption of ultraviolet radiation by the emulsion is very great.<sup>2</sup>

For this reason it was decided to set up a recording optical system where the exposure was confined to the single 3650 Å spectral line. This system is composed of a mercury arc light-source, ultraviolet filter, and a full quartz spherical condenser objective lens system, each element having a focal length of 3 inches. The optical system was further modified by providing a very small quartz cylindrical lens spaced 20 mils from the film and having a reduction of approximately 5 to 1 in the vertical direction.<sup>3, \*</sup>

\* Hardy has published information<sup>3</sup> on the use of the cylindrical lens in film-recording systems to change the magnification in one direction without change in the other direction.

Since this cylinder permits focusing the slit in the direction parallel to the slit, the rays that are at right angles to the plane of the slit must necessarily be focused at the plane of the film. This is accomplished by a cylindrical lens with axis perpendicular to the slit and placed immediately in front of the objective. This, then, gives an overall reduction of approximately 10 to 1 in the plane of the slit and a 2 to 1 reduction in a plane at right angles to the slit. Fig. 2 shows the schematic arrangement of the complete optical system.

Since the illumination is provided principally from the 3650 Å mercury line, a simple quartz optical system may be used. This reduces

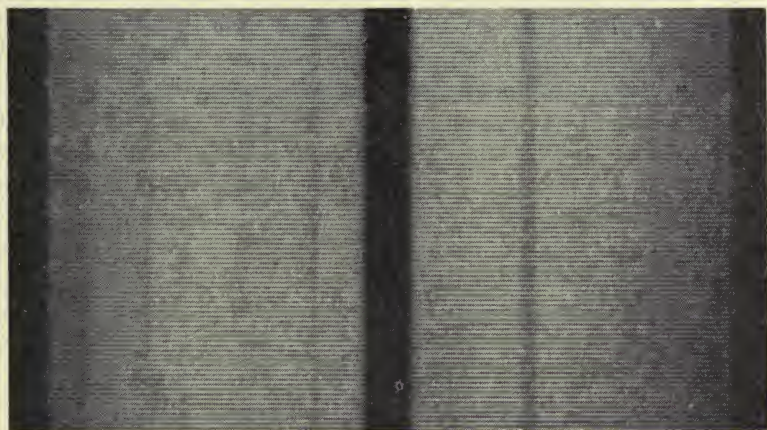


FIG. 3. Photomicrograph of sound-track made with the optical system described, when modulated at 14,000 cycles (reduced to 0.73 the size of the original photograph).

the need for chromatic correction in the lens system. It is recognized that quartz has the highest transmission in the range. Therefore the overall light efficiency is comparatively high and its supply is commercially available.

With this set-up the overall track illumination is much more uniform than has heretofore been secured by means of tungsten filament lamps and spherical lens only. As a result, when a push-pull track is made, the cancellation products are much improved at the higher frequencies, especially in the case of the wide (200-mil) push-pull track. Normally in corrected lens systems available today, the maximum cancellation obtained from a push-pull track when placed on a regular reproducer is 25 to 30 db at 1000 cycles and somewhat



lower at 7000 cycles. With the above-described system the cancellation is not less than 30 db for all frequencies over the entire range.

With this system, using the controlled air motor on the mercury arc lamp,<sup>4</sup> the density variation on the track is considerably more uniform than that which can be obtained with tungsten light. In push-pull recording the track balance between both halves is very important and laboratory daily density reports indicate balances within 0.02 over long periods of time. Fig. 3 shows a photomicrograph of a sound-track made with this optical system when modulated at 14,000 cycles.

The intermodulation terms obtained from this system due to ribbon-velocity effects are lower than those reported from any other system now being used in commercial production. Measurements using fine-grain negative and prints indicate less than 4 per cent intermodulation (approximately 1 per cent total harmonic content) as an optimum over a wide range of printer lights. Listening tests verify the degree of improvement by reducing to a minimum the effects of chromatic aberration, reduction of intermodulation, and non-uniformity of track illumination. It is believed that for the first time a variable-density recording system has been used in which a true monochromatic optical system in the ultraviolet range has been applied in commercial production. Valuable work was done by Mr. J. W. Stafford in the design and testing of this optical system.

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<sup>2</sup> FRAYNE, J. G., AND PAGHARULA, V.: "The Effects of Ultraviolet Light on Variable-Density Recording and Printing," *J. Soc. Mot. Pict. Eng.*, **XXXIV** (June, 1940), p. 614.

<sup>3</sup> HARDY, A. C.: "The Optics of Sound-Recording Systems," *Trans. Soc. Mot. Pict. Eng.*, **XII** (Sept., 1928), No. 35, p. 760; see also *J. Opt. Soc. Amer.*, **14** (1927), p. 505.

<sup>4</sup> DUPY, O. L., AND HILLIARD, J. K.: "Increased Illumination for Fine-Grain Recording," *Amer. Cinemat.* (Jan., 1940), p. 36.

#### DISCUSSION

DR. FRAYNE: I notice that Mr. Dupy is using a 1-mm 584 Corning filter. That filter does not make this a 100-per cent monochromatic system because it lets through about 25 per cent of the line at 4000 Å. I wonder whether he has made any test with the 2-mm 584.



MR. DUPY: An increase in the amount of filtering gives us only a reduction in light, and the light is sufficiently monochromatic to permit the use of an optical system lacking chromatic correction.

DR. SANDVIK: You might possibly get better image definition by using a molten lens. In that way it is possible to get lenses that are not cylindrical or of circular section. They are made by grinding a glass in a huge molten, and take a very fine polish. You could not use quartz, however, because quartz is too hard for the purpose. If you used a ground glass you would not get enough absorption at  $3650 \text{ \AA}$ .

MR. DUPY: That sounds interesting. At present we have a source of light and a cheap optical system that seem to stay with us. They are not perfect by any means, but form a tool that will at present work up to the limits of our knowledge of how to use them.

MR. HILLIARD: There seems to be an impression that the incandescent lamp is the most reliable source available to date. In our experience with the mercury-vapor lamp over a year's time, some of the lamps have stayed in the recorder as long as six months. With the motor control blower it is possible to produce variable-density film, or any exposure for that matter, with less deviation than has normally been recognized in the incandescent lamp system.

We have had as much as an 0.05 change in density on a negative with approximately 0.06 density; whereas over the period of a year's time we have been able to cut that down to approximately 0.02 with the controlled mercury-vapor light. For those who are interested in the laboratory part of the work it would appear profitable to utilize this function so as to obtain a controlled density in the released printing by this method. The laboratory people have felt that the incandescent lamp was the most foolproof, infallible, as well as the most uniform source, and I certainly would like them to consider the mercury lamp as such a replacement for the uniformity which they now have.

MR. LAUBE: Have you found it practicable to install mercury lamps in installed channels.

MR. HILLIARD: It is more practicable to install them in fixed channels, because there is some difficulty in using such a system with the regulated air-steam, as compared to the incandescent lamp. But in the case of release machines and in the laboratory, which is a fixed condition, there should be no objection to it, outside the fact that it does look slightly more complicated on the surface, and you may perhaps have to spend a little more money in the beginning to put it into operation. But it does give the possibility of obtaining a result in excess of what we are able to get at the present time, namely, the exposure of a fine-grain release.

MR. LAUBE: I understand that a feedback circuit has been devised that will keep the intensity of the lamp within very small fluctuations.

MR. HILLIARD: The motor-controlled blower is nothing but a mechanical feedback similar to the electrical feedback we use in amplifiers.

Equilibrium occurs when there is no change in exposure up to the degree of feedback that is allowed. When you get outside the limit, which is a matter, say, of 2:1 in exposure, then there is some exposure change. But where it is a matter of 5, 15, and 20 watts' change, there is more than enough feedback in the system to take care of the irregularity.

MR. LAUBE: I meant that the feedback principle may be used also with incandescent lamps.

MR. HILLIARD: I understand. I simply wanted to point out that we know what the limitation of melting tungsten is, as regards exposure, and the mercury-arc lamp does offer a source of intensity beyond that point.

MR. ALBIN: In the monochromatic system using quartz throughout, what was the effective change of gamma as compared to the ordinary glass incandescent source?

MR. HILLIARD: Are you speaking of the negative, or the overall effect?

MR. ALBIN: Everything but the negative.

MR. HILLIARD: Starting with a release negative gamma of approximately 0.4, it has been fairly well established that a reduction of 10 per cent can be obtained if the exposure is limited to the region around 3650 Å.

MR. ALBIN: How about the negative?

DR. FRAYNE: On the negative we found, for a 584 filter, a 15-per cent reduction in the negative gamma as contrasted to about 40 per cent in the positive.

MR. HILLIARD: It depends upon the filtering. I have gone down to a 3-mil 584 filter, and we estimate roughly a 15-per cent reduction at that point, which I think was very drastic.

MR. ALBIN: If this negative were used for release, it would be necessary to increase the negative gamma, that is, the developed gamma of the negative, by that percentage, and would tend to exaggerate any variation of density due to variation of exposure.

MR. HILLIARD: That is true. But you do get something else for your tendency to exaggerate, do you not?

MR. ALBIN: Yes.

MR. HILLIARD: It is a balance of one against the other, and depends upon which is the worse. I think we all recognize that the monochromatic element, both in printing and in exposure, has several decided advantages.

MR. ALBIN: But it merely speaks that much more for your control, the fact that you get less variation even with the higher gamma.

MR. HILLIARD: It depends upon our method of interpreting the gamma. A unity gamma is whatever the negative might be printed up in a reciprocal manner so as to get an overall unity gamma, is it not?

MR. KELLOGG: Mr. Hilliard, about how much change in light, as determined photographically, does a given percentage change in current produce, assuming that the change takes place so quickly that the temperature is constant. For example, if there is a sudden increase in current amount to 2 per cent, by what percentage would the light increase?

MR. HILLIARD: In the case of a sudden change of 2 per cent in current, assuming it changes so quickly the temperature is constant (which means the voltage is constant), the wattage increase is  $E \times (I \times 1.02)$ . Since the illumination is directly proportional to wattage, the illumination will change by 2 per cent. This corresponds to a density change of approximately 0.01 at a gamma of 0.42.

MR. KELLOGG: Did I understand Mr. Hilliard to say that he does not have a regulated supply?

MR. HILLIARD: Yes. When the arc voltage increases, the slower motor, which is tied across the arc terminals, also speeds up and forces more air through, which

decreases the arc voltage and tends to hold the illumination constant in spite of varying line voltage.

MR. KELLOGG: Has that been satisfactory with various power sources?

MR. HILLIARD: It has seemed to be. In the daily logs sent up by the laboratory there has been no reported deviation in excess of 0.02 to 0.03 in density at the nominal 0.6 normal density.

MR. KELLOGG: Do you have to filter the supply pretty well?

MR. HILLIARD: Yes, to get the ripple out, because the instantaneous effect of the mercury light would record naturally any 50 or 100-cycle components that might be in it. There is considerable inductance and capacity to give a "fly-wheel" effect.



## SOME OBSERVATIONS ON LATENT IMAGE STABILITY OF MOTION PICTURE FILM\*

K. FAMULENER AND E. LOESSEL\*\*

*Summary.*—The observations reported are the result of an investigation to determine the effect of a delay between the exposure and development of modern motion picture films. The stability of the latent image in terms of speed, gradation, graininess, and color response has been studied.

In general, a definite speed increase was noted on negative emulsions, a decrease on positive emulsions. There were also changes in gradation and graininess. The detailed findings which vary considerably with the individual emulsion type are given, followed by a general discussion and interpretation of the results. A brief review of the literature is included.

A little over a year ago we started an investigation of the effect of age on the photographic latent image. This, prompted by a desire to determine the effect of a delay between the exposure and development of motion picture films, embraced cine positive, infrared, and three speed ranges of panchromatic negative films.

There are, in the photographic trade, many fixed ideas on the result of delaying development after exposure, most of them contradicting each other. In view of these conflicting beliefs it is surprising that so few actual investigations have been made and reported in the literature. It is even more surprising that such a small portion of those that did appear were well organized and yielded valid results.

Our literature search uncovered many articles based either upon unsubstantiated opinions or incomplete and misleading investigations. In fact, this led E. Heisenberg<sup>1</sup> to remark, "It is striking that in almost all the older investigations only a regression of the latent image has come to the foreground." We shall mention only a few of these older investigations in passing and devote our time to the more careful research work done by Bullock, Heisenberg, Jausseran, Mees, and others.

As long ago as 1889 Bedding<sup>2</sup> called the continuing action of light

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\*Presented at the 1940 Fall Meeting at Hollywood, Calif.; received October 5, 1940.

\*\*Agfa Anco Corp., Binghamton, N. Y.



after exposure, "a pretty little photographic heresy." On the other hand, W. I. Rogers<sup>3</sup> mentioned in 1891 that plates known to be underexposed can be intensified by delaying development for several weeks. C. E. K. Mees<sup>4</sup> in 1915 observed a speed increase if development of the latent image was delayed, and G. Jausseran<sup>5</sup> discovered in 1929 a linear relation between the logarithm of the delay time between exposure and development and the resulting density. This was confirmed by E. R. Bullock<sup>6</sup> in his very thorough and extensive work on the subject.

Various reports on factors causing or influencing changes in the latent image have appeared. J. Barker<sup>7</sup> found bromide emulsions more stable than iodide or iodide-bromide emulsions. Bakeland<sup>8</sup> reported greater stability of neutral or weakly alkaline emulsions compared to acid emulsions. According to Heisenberg<sup>1</sup> the growth of the latent image on panchromatic emulsions is due to the sensitization, and according to Bullock<sup>6</sup> it varies with the development gamma and the speed of the emulsion. The wavelength of the exposure light and the strength of the developer are also factors.

These investigators were guided principally by theoretical interests and were not concerned with the practical significance of latent image intensification. Their investigations were for the most part concerned with deriving a law defining the latent image intensification or regression with time, which would allow this phenomenon to be interpreted in terms of the latest theory explaining the physico-chemical nature of latent image formation.

On the other hand, the tests which are to be reported here were carried out under average working conditions to obtain data that would interest the motion picture cameraman and film technician. They are, it is true, more qualitative than quantitative, but permit valid conclusions to be drawn.

In our investigation the effect that aging the latent image has on the speed, gradation, general shape of the  $D$ -log  $E$  curves, graininess, and color response of the developable image was studied. Our results may be used to answer such practical questions as: How well do various films keep after exposure but before development? What changes in speed and gradation take place when development is delayed and are they sufficiently great to merit serious consideration? Is special exposure and development necessary to obtain the best results when it is known at the time of exposure that there will be a considerable delay before development?

We selected for this work widely used motion picture films manufactured in this country. They were representative of the high-speed, medium-speed, and low-speed panchromatic and infrared negative films as well as motion picture positive. The procedure which we worked out was to cut from each film under investigation 104 4-ft 35-mm strips. Half of these were exposed on a time-scale sensitometer at the beginning of the study. The other half were exposed on the same apparatus once each week during the investigation. Two butted exposures with the lamp and filter appropriate to the particular film were made on each strip. Once each week one of the originally exposed strips and a freshly exposed strip were developed simultaneously on a developing machine using the developer and time of development most suitable to the emulsion being studied. Since the strips were always developed together variations in development were cancelled out. Both the exposed and unexposed strips were stored during the course of this investigation in taped cans at a temperature of approximately 70°F and relative humidity of 50 per cent. The films were handled both before packing and during exposure under these same conditions of temperature and humidity. After development the strips to be compared were read, averaged, and their  $D$ -log  $E$  curves plotted. These plots furnished us with the basic sensitometric data.

Practical camera tests were made in addition to the sensitometric measurements. A set of pictorials, exposed in a Leica camera at  $1/2$ -stop intervals, was made on the first part of each of two 36-exposure cartridges at the beginning of the investigation. A dummy test set was used and the position and intensity of lights, camera position, *etc.*, carefully measured and recorded. A photoelectric photometer gave a rough value for the illumination level. This enabled us to duplicate the set for later tests. Four months after the beginning of the investigation another series of exposures were made on one of the cartridges and eight months later on the other. These were machine developed immediately following exposure of the second cartridge. Thus pictorial comparisons were prepared of film developed immediately after exposure and the same film developed four and eight months, respectively, thereafter. Due to the looser control of the duplication of the pictorial tests, the results obtained from these have more a corroborative than absolute value. An Agfa step color-chart was used in these pictorials to give us an indication of any change in the color response values.

The results of the investigation are shown in the figures illustrating the detailed discussion. We have, plotted on one chart, curves for development, 0, 13, 26, 39, and 48 weeks after exposure. These were obtained by averaging the curves representing the film developed immediately after exposure and relating the other curves to this average. The detailed results which this data yielded were as follows:

*High-Speed Panchromatic Negative.*—In Figs. 1 and 2 are shown the curves obtained on two competitive high-speed motion picture negative films. In Fig.1 it is seen that as the development of the

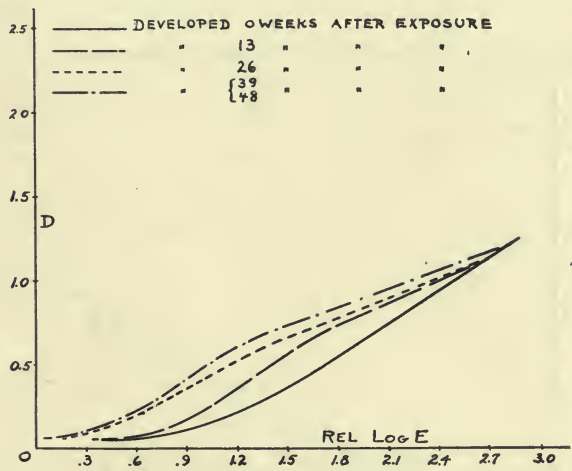


FIG. 1. Latent image age effect on high-speed panchromatic motion picture negative film no. 1.

film is delayed longer and longer after exposure, the apparent speed of the film increases. This increase is, during the first four weeks, slight and general for the entire characteristic curve. After five weeks of delay the film begins to show a preferential speed increase at densities around 0.6. This continues with age and constantly extends further into the toe section. When 39 weeks have elapsed the characteristic curve has lost all resemblance to the curve obtained from the same film freshly exposed and developed. There is a speed increase of  $2\frac{1}{2}$  stops at a density of 0.6 above fog and above this value the film is flatter, and below, steeper than the same material developed immediately after exposure. Thirteen weeks later the curves show little additional change. Pictorial tests developed four



and eight months after exposure demonstrate a speed increase in the toe region of  $1\frac{1}{2}$  and 2 stops, respectively. In both cases the pictorial gradation was lower than that of the same film exposed and developed without delay.

Grain enlargements made from both pictorial and sensitometric strips indicate an increase in graininess with delayed development. The color-sensitivity from step color-chart readings shows a drop in blue and green relative to the red and yellow.

The changes in the sensitometric characteristics of the film shown in Fig. 2 differ from those found on the film represented by Fig. 1.

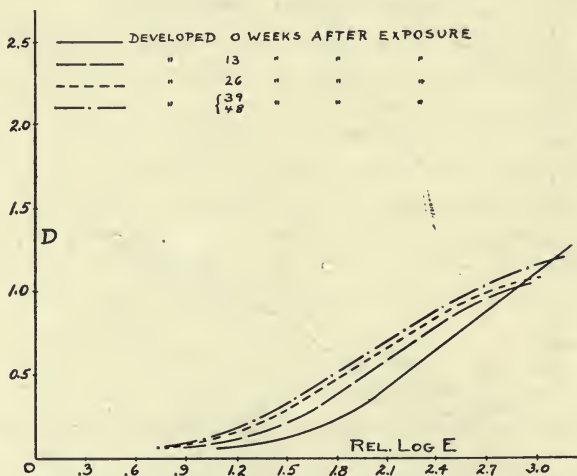


FIG. 2. Latent image age effect on high-speed panchromatic motion picture negative film no. 2.

There is a rapid increase in speed, a full stop being noted after only three weeks. Six weeks after the exposure, the speed increases  $1\frac{1}{2}$  stops and there is no appreciable change in speed for longer intervals between exposures and development. There is a slight decrease in contrast with delayed development. Enlargements made from the sensitometric strips showed a barely perceptibly greater graininess on the film which was exposed 48 weeks before development compared with that exposed immediately before development.

Thus for high-speed panchromatic films there is an increase in speed of from  $1\frac{1}{2}$  to  $2\frac{1}{2}$  stops, a decrease in gradation and a slight increase in grain.



*Medium-Speed Panchromatic Motion Picture Negative Films.*—The films that we have classed as medium-speed panchromatic negative motion picture emulsions are those which each of the leading American film manufacturers offered two years ago as a standard motion picture negative material. It is these which were used for all routine studio production work.

The greatest speed increase was noted on the film shown in Fig. 3 which was found to be  $1\frac{1}{2}$  stops faster with a 13-week delay and 2 stops faster with a 39-week delay than comparison strips developed immediately after exposure. The characteristics appear to be stable

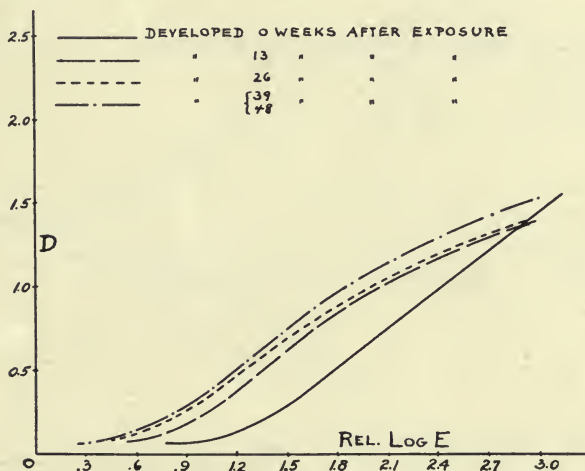


FIG. 3. Latent image age effect on medium-speed panchromatic motion picture negative film no. 3.

after 39 weeks, no significant change being noted after 13 more weeks of aging.

The film shown in Fig. 4 exhibits a faster latent image growth than that in Fig. 3 and little change after 13 weeks save for growth in the shoulder densities. There appears to be no change whatsoever after 36 weeks' aging at which time the speed increase is slightly more than  $1\frac{1}{2}$  stops.

In Fig. 5 we noted a similar effect, the film gaining 1 stop in speed during the first 13 weeks,  $1\frac{1}{2}$  stops during the first 26 weeks and showing little change thereafter. Pictorials bear out the sensitometric results obtained on these three films. In all cases there is a slight coarsening of grain with age and little change in color re-

sponse. Aging of the latent image brings about a pronounced softening in highlight gradation on the film shown in Fig. 3 and a very slight softening on those shown in Figs. 4 and 5.

*Fine-Grain Panchromatic Motion Picture Negative Film.*—Under this classification only one film was tested. The results are shown in Fig. 6. Here latent image age resulted in a speed increase of  $1\frac{1}{2}$  stop in 13 weeks,  $1\frac{1}{2}$  stops in 39 weeks, and 2 stops in 48 weeks. There is a definite decrease in gradation in the high densities above 1.0, a steepening in the lower densities. Pictorial tests showed an increase in speed of 1 to  $1\frac{1}{2}$  stops with a loss in highlight gradation.

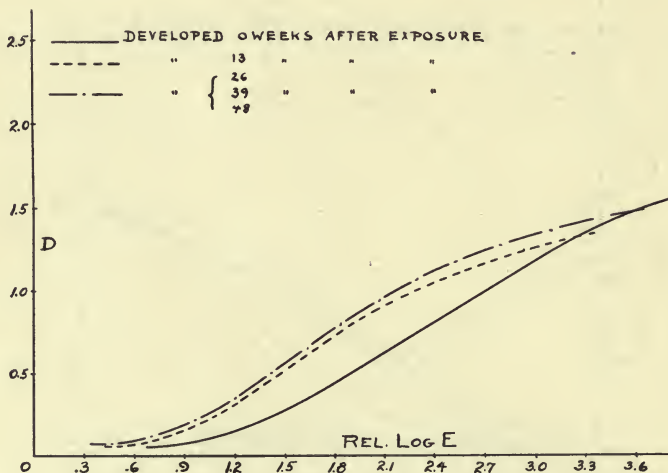


FIG. 4. Latent image age effect on medium-speed panchromatic motion picture negative film no. 4.

There was a definite coarsening of grain with the age of the latent image which will be discussed later. Color-chart readings showed a drop in blue-green response compared with the red-yellow.

*Infrared Negative Motion Picture Negative Film.*—One infrared motion picture film was tested with the results shown in Fig. 7. It will be noticed that there is a slight increase in speed and a very slight loss in gradation with latent image aging. The speed increase is of the order of  $1\frac{1}{2}$  stop and there is little change after 13 weeks save an increase in toe speed.

*Cine Positive Emulsions.*—Two motion picture cine positive emulsions were tested and the results plotted in Figs. 8 and 9, respectively.

In Fig. 8 we find that there is very little change in speed or gradation with latent image aging. Matched densities from strips exposed immediately before development and strips exposed one year before

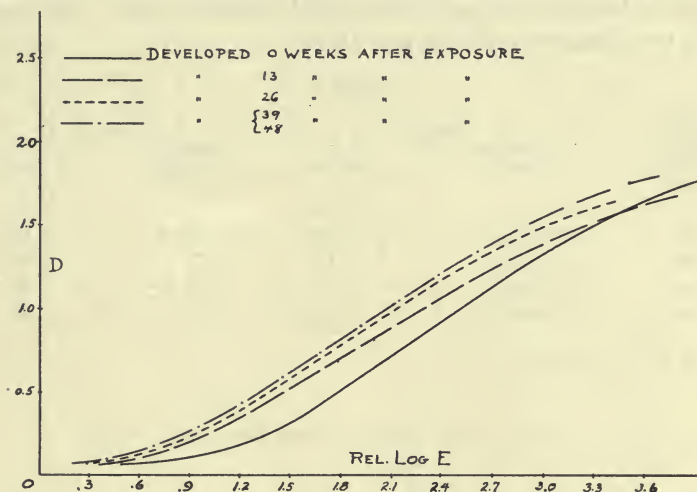


FIG. 5. Latent image age effect on medium-speed panchromatic motion picture negative film no. 5.

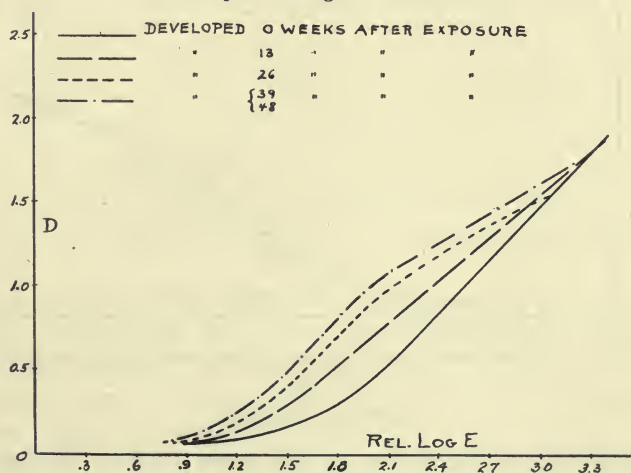


FIG. 6. Latent image age effect on fine-grain panchromatic motion picture negative film.

development were projected side by side and no appreciable grain noted on the screen. The effective enlargement was about equal to that obtained in the average motion picture theater,

In Fig. 9 there was a marked decrease in speed with age amounting to approximately 7 printer points in 13 weeks and rising to about 15 printer points in 39 weeks. Grain projections showed no discernible difference between the aged and freshly exposed film. The results on the two films are best shown in Table I.

TABLE I

Latent Image Age before Development (weeks)	Change in Speed	Film No. 8 Gamma	Film No. 9 Change in Speed (points)	Gamma
0		2.06		2.20
13	Vy sl* -	2.04	7 +	2.00
26	Vy sl +	2.12	12 +	1.90
39	Vy sl +	2.12	15 +	1.66
48	2 points +	2.08	15 +	1.66

\*"Vy sl" = very slight.

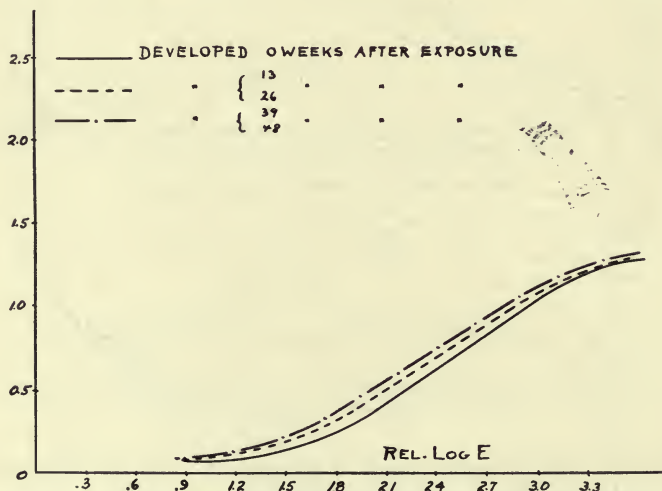


FIG. 7. Latent image age effect on infrared motion picture negative film.

#### GENERAL RESULTS

*Intensification or Regression of the Latent Image with Age.*—The test results obtained under the different emulsion groups indicate that the intensification or regression of the latent image varies with several factors. First, we find, as Heisenberg contended, that the intensification is most pronounced with color sensitized emulsions. All the sensitized negative materials show a speed increase of from



$\frac{3}{4}$  to  $2\frac{1}{2}$  stops. The two positive films which, of course, were not sensitized, showed no change and a decided regression of the latent image, respectively. Furthermore, it is apparent that the greatest intensification of the latent image is to be found on films with a high initial sensitivity. The high-speed films showed an increase in speed of approximately 2 stops, medium-speed  $1\frac{1}{2}$  to 2, and the slow-speed films 1 stop, while with infrared there was a  $\frac{3}{4}$  of a stop increase. This confirms Bullock's claim that the degree of latent image intensification varies with the initial emulsion speed.

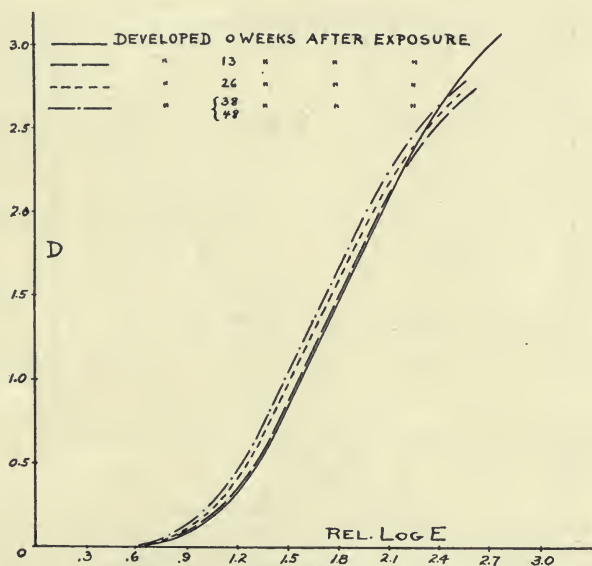


FIG. 8. Latent image age effect on motion picture positive film no. 8.

Bullock noted that the advance in speed is most pronounced at densities near 0.6 which was confirmed on several films. However, our tests showed sufficient exceptions for us to conclude that this initial increase in speed in the neighborhood of 0.6 is not a necessary accompaniment of latent image age.

The shoulder of the characteristic curve does not show as marked an image growth as do the lower densities. In some cases, in fact, a regression may occur at extremely high densities. This indicates that the intensification or growth effect depends upon the exposure and may reverse itself at high levels. The densities at which no growth or decay takes place, *i. e.*, at which the two characteristic

curves intersect, is an ideal point at which to make comparisons of other age effects.

Jausseran derived a logarithmic relation between the intensification and time lapse between exposure and development. This was later confirmed by Bullock. However, the ages considered were in units of seconds rather than weeks, the longest interval between exposure and development being five hours. Bullock implies further that the growth effect does not continue long and says, "Since the rate of

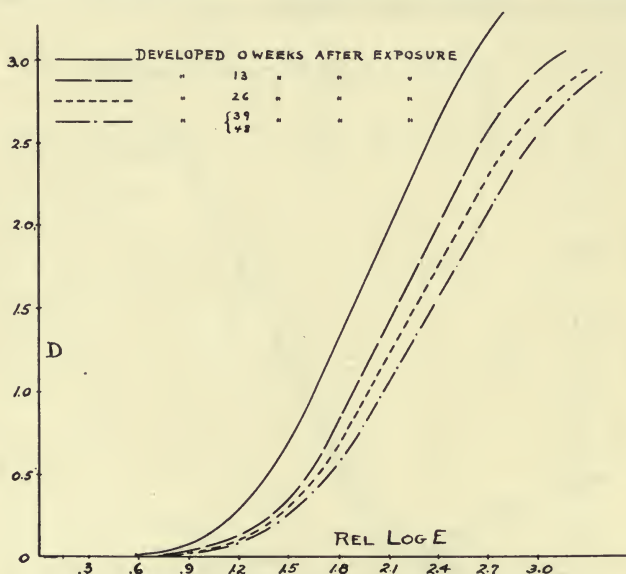


FIG. 9. Latent image age effect on motion picture positive film no. 9.

increase of the latent image may. . . be taken as inversely proportional to the time, the practice of keeping exposed material for a few hours or overnight whenever it is desired to develop non-simultaneous low intensity exposures simultaneously, is to be commended." Our work extending over periods of months rather than hours showed a latent image growth far beyond the "overnight" period that Bullock mentioned. We can not establish a definite law for this growth but in general it approaches a logarithmic function.

The effect is not, as Bullock states, general for all emulsions, since the positive emulsion discussed under Fig. 9 shows a definite regression. However, again we must remember that Bullock speaks in

terms of hours and we in terms of months, and it is possible that there is an increase of the developable image for a short time after exposure followed by a regression. This regression is not even necessarily related to the growth or intensification effect. In fact, at no time in our work did we observe the growth effect followed by regression of the developable image. On the contrary, the growth effect reached a maximum which was maintained throughout the balance of the test. The time required to reach this maximum varied with the individual emulsion from a few weeks to 9 months but was not characteristic

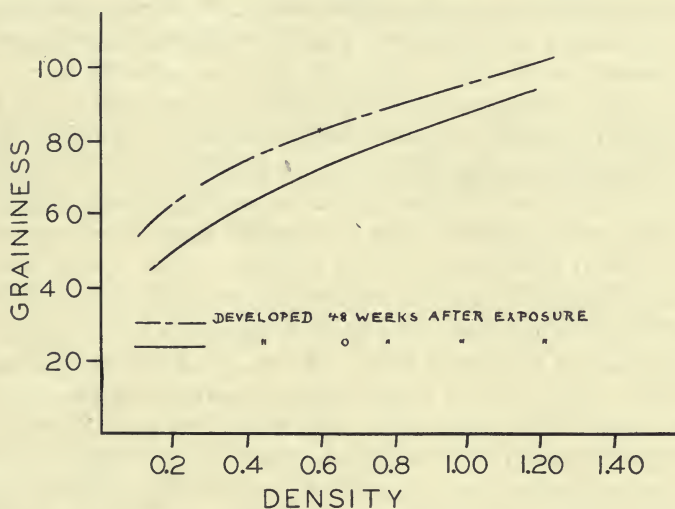


FIG. 10. Graininess-density curve for high-speed panchromatic motion picture negative film no. 1.

of any particular emulsion grouped according to speed or sensitization. In comparing Bullock's results with ours, it should be remembered that besides the difference in magnitude of the intervals studied he used an intensity-scale exposure method while we used a time-scale method.

*Effect of Image Growth on Grain.*—Our investigations showed that in many cases the growth of the developable image with age was accompanied by an increase in graininess. In order to get a better approximation of the difference in graininess than that afforded by grain enlargements, use was made of the graininess meter described by Goetz.<sup>9</sup> The graininess-density curve for the higher speed panchromatic negative film, whose sensitometric curves are given in

Fig. 1, is shown in Fig. 10. From Fig. 1 we note that there has been no image growth at a density of 1.20. However, the density graininess curves do not approach each other at this density. Therefore, it appears that while the developable image becomes more grainy with age, this increase in graininess does not account for the increase in density.

*Color-Sensitivity and the Growth Effect.*—LeClerc in "Photography: Theory and Practice" says that Jausseran found that the growth effect is not the same for latent images produced by different radiations. In our work no more accurate check was made on the dependence of the growth effect on the spectral quality of the original exposure than was afforded by the Agfa step color-chart in pictorial tests. This indicates that there was less growth in the blue and green than in the yellow and red range on panchromatic emulsions. However, further work is being done using more accurate methods. One would expect less growth effect with a blue light exposure since it has already been established that growth of the developable image is closely related to the optical sensitization of the emulsion. Our results with unsensitized emulsions, such as motion picture positive film, show no growth effect in one case and a decided regression in the other.

*Mechanism of the Growth Effect.*—We do not feel that our data are sufficiently refined at the present time to permit conclusions on the mechanism of the growth effect. However, we have found in this investigation some facts that substantiate and some that contradict the theories that have been advanced to account for the phenomenon. We do not wish to discuss these until further more accurate work has been done.

#### SUMMARY

This investigation may be summarized as follows:

(1) This investigation differs from those of previous workers by tracing the change of the developable image over a period of a year rather than for several hours after exposure.

(2) A growth of the latent image varying from  $1\frac{1}{2}$  to  $2\frac{1}{2}$  stops was found in all the negative films tested.

(3) No intensification in one case and a decided regression in another was found with cine positive films.

(4) The growth effect depends upon the sensitivity of the emulsion, is more pronounced in fast than in slow emulsions.



(5) The intensification effect is most pronounced at low densities, and may be entirely lacking or replaced by a regression at high densities.

(6) The growth effect depends on the optical sensitization of the emulsion. Unsensitized emulsions show little growth effect, sometimes decided regression.

(7) The growth effect results in increased graininess but this increase is not sufficient to account for the gain in density.

(8) The spectral quality of the exposure illumination may influence the growth effect. This is suggested by the present work but requires a more accurate method for verification.

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<sup>8</sup> EDER, J. M. (Editor): "Jahrbuch für Photographie und Reproduktionstechnik für das Jahr 1904," *Wilhelm Knapp, Halle a. S.*, **18** (1904), p. 392.

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#### DISCUSSION

MR. LESHING: With regard to positive film, our experience from day to day shows a considerable and rapid loss of image measured, not in weeks or days, but in hours and minutes. The loss of image is sufficient to make us split up our night's work into small portions and to avoid keeping our Cinex tests any length of time before development.

MR. COOK: This investigation started where previous investigations have left off. The prior work has pointed out that appreciable and important changes in the latent image may take place a very short while after exposure. Detectable changes may occur even within a few seconds. However, our investigation was

not primarily concerned with these small time intervals. We found that motion picture positive emulsions of various manufacture varied greatly one from another in the rate of latent image regression.

MR. HUSE: It is Hollywood practice to make sensitometric exposures some hours ahead of their actual use. For example, the exposures may be made in the morning for use that night. Investigation has shown a more marked regression of the latent image during the first few hours after exposure—beyond which the change is slight and progresses very slowly.

MR. CRABTREE: What is the difference between the results obtained with film on a nitrate base and film on an acetate base? Also, what is the effect of high humidity and high temperature in the result?

MR. COOK: We are not prepared to answer Mr. Crabtree's questions at the present time. However, this investigation is being continued and we believe that Mr. Crabtree's queries will be answered when our later findings are published.

## NEGATIVE EXPOSURE CONTROL\*

DON NORWOOD\*\*

*Summary.*—It would be desirable to have negative exposure control on the basis of an exact science. Toward this end the functioning of the eye as it views a subject and the photographic reproduction of the subject is studied. The brightness of the subject is broken down into its components of reflectance (a constant) and incident illumination (a variable). The eye compensates for changes in the illumination. The "tone" of the object is based on its reflectance. It is this that determines the print density used to portray the object. Between the subject's fixed reflectance and the print's fixed density lies the variable of negative density.

A system is proposed whereby given reflectance in the subject is represented by fixed density in the negative. Operation of the system involves negative exposure control by measurement of incident light. Measurement of effective incident illumination is accomplished by a photoelectric meter specifically designed to respond to the three-dimensional characteristics of incident illumination. The system is free from many of the influences which tend to cause undesirable variations and errors in negative exposure. It provides a means of putting negative exposure control on the basis of an exact science.

Every time his camera shutter clicks, probably every photographer utters a little inward prayer to the effect that, "Please may the exposure be right!" For once the shutter has clicked, the die is cast, the Rubicon has been crossed, the deed has been done. Thereafter all the king's horses and all the king's men can not appreciably improve the effect of that exposure. The quality, not only of the negative, but also of the print to be made therefrom, depends in large measure upon the correctness of that exposure. Thus it will be appreciated that negative exposure control is a subject of considerable importance to every photographer.

If negative exposure control had the status of an exact science, the photographer would be able to take for granted that his exposures would be correct every time. As a step toward this very desirable objective, the purpose of this paper is to discuss various phases of negative exposure control. It is hoped to clarify to some

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\*\* Hollywood, Calif.

extent a subject that has developed some rather confusing phases. There will be described some simple tests, in which the action of exposure meters will be examined.

Negative exposure bears a rather close relationship to several other elements concerned in picture making. A close examination of some of these elements, and the relationships between them will serve to bring out some rather interesting facts.

One of the elements is the appearance of the photographic subject to the human eye. It is this appearance that we hope to reproduce, within photographic limitations, in the print. Another element is the appearance of the photographic subject in the print. Still another is the exposure that must be used to make the print from the negative, and yet another is the matter of subject brightness and its components of incident light and reflectance.

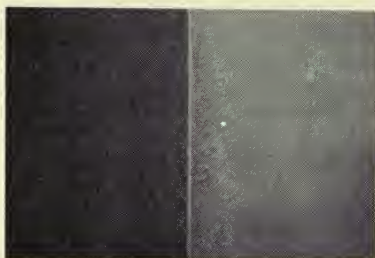


FIG. 1. Two-card test panel.

Let us consider a simple case, and note how the various elements and relationships are affected. Fig. 1 is a panel composed of cards showing two shades of gray. Suppose that a picture were to be made to include this panel and nothing else. Any experienced photographer, upon viewing the panel, can form a mental picture of how a paper print should reproduce what he sees here. His mental picture will establish fixed densities of silver deposit on the print, which will serve to reproduce what the eye sees first hand.

Upon turning on additional light, the intensity of illumination on the panel, which previously was just nominal, will be increased many-fold. During a short transition period the panel will appear intensely bright, but after a short lapse of time one becomes accustomed to the new level of illumination.



Now suppose that another picture of the panel is to be made. The photographer is asked to visualize the appearance of the paper print. In all probability his visualization of the second print will be identical with the first. This is not hard to understand when the mechanism of the eye is considered. The eye has the property of adaptation. It automatically adapts itself to compensate for changes in brightness.

Brightness of any object is a product of two elements: namely, incident illumination, a variable quantity; and reflection, a fixed quantity. The eye acts to compensate for changes in the variable, the incident illumination; the mind judges the appearance of the object in relation to other objects by the fixed element, the reflection factor.

The reflection factors are the means by which we distinguish between the two grays on the panel. One gray has a low reflection factor, one has a higher reflection factor. It is an appreciation of these reflection factors that enables the photographer to determine how he will make these grays appear in a print. Thus we can say that a fixed relationship exists between the reflection factor of an object, and the density of the silver deposit that will represent it in a print.

What is the range of reflection factors likely to be encountered in photographic practice? Diffuse reflection factors might extend from 0 to 100 per cent. However, we find that all objects having a diffuse reflectance of 4 per cent or less are called black. Black velvet has a reflectance of 2 per cent. At the other end of the scale, about the brightest diffused white encountered is white velvet, which has a reflectance of 80 per cent. Thus the limits encountered in practical work are 2 per cent and 80 per cent, or a ratio of 1 to 40.

Now, considering negative materials, modern negative emulsions have a range of about 1 to 125. This is quite a large range into which to fit a subject brightness range of 1 to 40. In fact, it may leave considerable unused latitude at each end of the negative scale. This extended negative latitude has been useful in the past when the only means of exposure determination were somewhat lacking in precision. However, due to this same extended negative latitude, the development of a precise system of negative exposure control has probably been somewhat retarded. The prevailing thought has possibly been that if errors in negative exposure could be compensated by variations in printing exposure, then what was the difference?

The arrival of natural color film with its considerably narrower exposure latitude has changed this attitude in some cases.

Let us examine the situation developed in this discussion thus far. The reflection factor of an object is a constant. The print density used to represent this object is a constant. Between these two is an intermediate step, which involves the negative density used to represent the object. Heretofore this negative density has been a somewhat uncertain variable, as can be illustrated by some examples. Suppose we are going to make a picture of our panel, and for exposure guidance we shall try a photoelectric exposure meter of type responding to reflected light. One method of using this meter consists in measuring the brightest portion of the subject, also the darkest portion, and then computing the mean of the two on a geometric scale. This gives a figure representing the mean between the high-

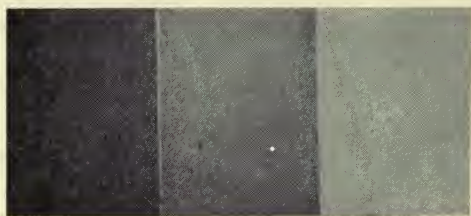


FIG. 2. Three-card test panel.

est and lowest values of reflected light. A setting for the camera exposure controls is then computed from this figure.

Now suppose, still using this method, that an additional card is introduced into the picture area, as shown in Fig. 2. This card has a considerably higher reflection factor than the two previously in the picture area. More light is reflected from it. Now, one meter reading will be taken on it, and one on the low-reflectance card. The mean of the two readings will be quite different from that previously obtained. Consequently, the exposure on the film will be different from the previous exposure, and the two grays on the original panel will be represented by changed densities in the negative. A still different shift in negative density will occur if the two higher-reflectance cards were eliminated, and one reading taken on the low-reflectance card only.

Let us examine the action of this type of meter a little further. Suppose we take a reading on the low-reflectance card only, and

make an exposure of this card only, in accordance with the reading. Next we take a reading on the medium-reflectance card only, and make an exposure of this card in accordance with its reading. Last, we take a reading on the high-reflectance card only, and make an exposure of this card in accordance with its reading.

Under conditions of constant illumination the three readings will be in proportion to the reflection factors of the three cards. The exposure control settings dictated by the meter will vary in inverse ratio to the reflectances of the cards, the end-result being that when the films are developed the three negatives will all be of the same density. The reflectance identities of the subjects will have been lost in these identical negatives.

Now suppose that paper prints are to be made from these negatives. One print must be of low reflectance to represent its original correctly. The next must be of medium reflectance, and the third high reflectance. To arrive at these effects in the prints, from three negatives of identical density, it is obvious that the first must receive a comparatively great printing exposure, the second an intermediate exposure, and the third a very small printing exposure.

This analysis shows that the reflected-light type of meter, even when most carefully used, will not give negatives of uniform characteristics, so that all may be printed with the same printing exposure. The property of those meters that causes the above-described result also causes exposure errors on short-scale reversal film such as Kodachrome.

A different method of using this type of meter is known as the average-brightness method. With this method the meter is held at some position where it encompasses the whole scene at once. The reading so obtained represents the average brightness of the whole scene, and is frequently used to determine exposure control settings.

In illustrating this case let our scene be limited by a frame which includes portions of the two grays on the panel. It will readily be apparent that the meter readings will change as the frame is moved around to include different relative proportions of the two grays. In position *A*, which includes equal portions of both grays, one reading will be obtained. In position *B*, which includes a large portion of high-reflectance material and a small portion of low-reflectance material, a much higher reading will be obtained. In position *C*, which includes a small portion of high-reflectance material and a large portion of low-reflectance material, a much smaller reading will be



obtained. This variety of readings for two subjects of constant reflectance, under constant illumination, will not give us the uniformity of results we are seeking.

The author has developed an instrument that circumvents the difficulties just mentioned, but before this instrument is described a brief discussion of subject and image brightness is needed. In looking at the panel of Fig. 3 there is a temptation to classify the two grays by saying that one is a dark gray and one is a bright gray.



FIG. 3. Varying areas affect the total light reflected to the brightness meter.

This manner of speaking and thinking is inaccurate, and possibly leads to a confused conclusion, because if the incident illumination is raised, the present dark gray may become many times brighter than the former bright gray. A much more orderly way of identifying these grays is by reference to their respective reflection factors, which are fixed quantities. If the exact figures are not known it would be proper to say that one gray has high reflectance and one low reflectance.

These same relative reflectance values will be achieved in the prints in order to reproduce as nearly as possible the appearance of the original. It will be realized that the print may be viewed under



high or low levels of illumination, just as the original was viewed under either condition. The compensating mechanism of the eye will be at work in either case to keep the retinal image at the level desired by the mind.

Since the reflection factor of the subject, a fixed quantity, is of such importance in identifying the subject, the author proposes a system of negative exposure control in which each reflection factor is represented on the negative by a given density of silver deposit. Thus the identity of any given subject reflectance will be preserved in the negative.

This idea may be graphically portrayed by means of an H&D curve, as shown in Fig. 4. An interesting point to note is that flesh

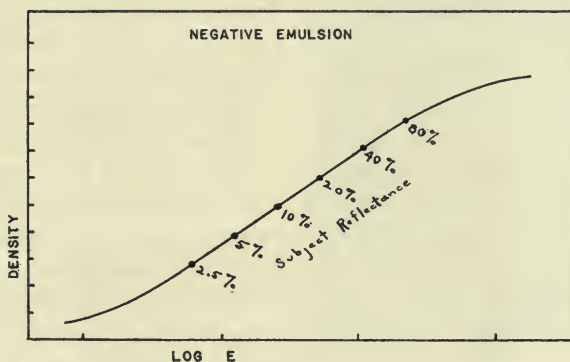


FIG. 4. Subject reflectance on  $D$ -log  $E$  curve.

tones, having a reflectance between 30 and 40 per cent, fall on a very desirable portion of the curve. This system for controlling negative exposure is based on the fact that subject brightness can be broken down into its components of reflection factor (the fixed quantity) and incident illumination (the variable).

The reflection factor is to be represented in the negative by a given density of silver deposit. It then follows that the variable element of subject brightness, incident illumination, must be compensated by adjusting the lens aperture and the shutter speed. The three variables of incident illumination, the lens aperture, and the shutter time, are firmly bonded together. A change in incident illumination imperatively requires a compensating change in  $f$ /value or shutter time. The scientific determination of the  $f$ /value and shutter speed

thus inevitably requires a measurement of incident illumination rather than reflected light.

Under the conditions we have set up for this panel (Fig. 3) a measurement of incident illumination would be comparatively simple. From the position of the subject, or panel, we could point a photoelectric meter, properly calibrated, at the light-source, which is presumably located beside the camera. The value of the incident illumination would be determined by the meter, and from this value the proper exposure would be computed. Changes in the panel, such as the addition of other cards having different reflection factors, would have no effect upon the result. The camera exposure controls

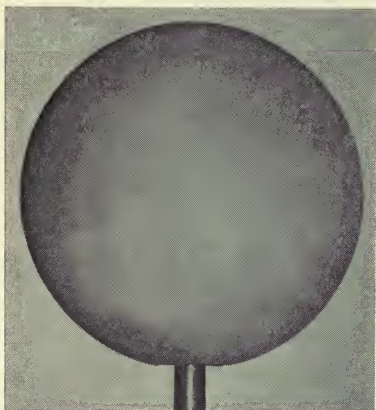


FIG. 5. Modified reflectance on spherical surface.

would always be set to compensate for changes in the incident illumination. Objects in the scene would always be recorded with given densities which would correspond with their respective reflectances.

Three forms of departure from this simple case must be recognized. One of these is due to the fact that most photographic subjects are not plane surfaces like the panel. They are three-dimensional, having planes and curves arranged spatially at many different angles. For example,

consider the sphere shown in Fig. 5. Even if the illumination on the sphere were perfectly uniform from the front, the portion directly toward the camera would reflect somewhat more light toward the camera than the other sides in accordance with Lambert's cosine law. Due to this law the camera would see the central portion as brighter than the sides. This effect, however, is very fortunate, since it duplicates the effect that the subject makes upon the human eye. The end-result will be that the print will represent the sphere just as the eye sees it.

However, due to this effect it would be desirable to use the term "modified reflectance" when considering the portions of a photographic subject which are subjected to its influence. This refers to reflectance as seen and evaluated from the camera position. So

much for the effects of surface angularity acting to produce modified reflectance values.

Another type of modified reflectance is produced by local variations in illumination within the scene. For example, visualize a white stucco garden wall. The sun is shining on it; however, there are local obstructions to the primary light, in the form of trees which cast leaf shadows on the wall. Under such a set-up we shall find that conditions of modified reflectance exist. Such a set-up may fall into any one of three classifications:

First, the wall may be almost clear, with only a few leaf shadows. In this case the prevailing illumination would be the direct light from the sun. The few shadow parts of the wall would be considered as having modified reflectance.

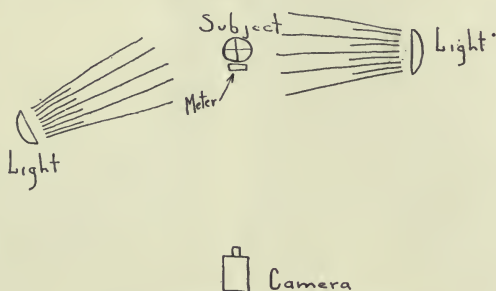


FIG. 6. Balanced side lighting.

Second, the wall might be almost covered with shadows, with only a few shafts of sunlight shining through to strike it. In this case the prevailing illumination would be that existing in the shadows. The few bright spots would then be the ones having the modified reflectance.

Third, the proportions of light and shadow on the wall might be roughly equal. In this case the prevailing illumination would be considered to be a mean between the direct sunlight and the shadow light. The result would be that both highlights and shadows would have modified reflectance values with respect to the prevailing illumination.

The concept of "prevailing illumination" on a photographic scene is an important one. When the eye looks at a scene the adaptation mechanism functions and assumes some set adjustment. This adjustment recognizes the value of prevailing illumination,



and compensates therefor. A corresponding adjustment of the camera exposure controls is necessary if the negative is to be exposed properly. The proper adjustment for these controls may be determined from a measurement of the prevailing illumination. As the eye adapts itself to view the scenes, so will the camera exposure controls be adapted. The proposed system thus follows the natural action of the eye; what the eye sees in the way of tones the camera will also see.



FIG. 7. Prevailing-illumination meter. FIG. 8. Effect of front light on collector.

The other major form of departure from the simple case comes from the fact that illumination on a photographic subject does not always, or even usually, come from a point adjacent to the camera. The illumination may come from almost any direction with respect to the camera-subject axis, and may come from several directions at once. This situation makes difficult the use of a plane-surface photoelectric cell to measure the incident light, such as was used to measure the light on the panel.

For instance, light striking on the side of a three-dimensional subject is quite effective in illuminating it, as illustrated in Fig. 6. The plane-surface cell does not properly evaluate this illumination.



In order to get a device which will properly evaluate this illumination it is necessary to go to a photoelectric meter which has a three-dimensional light pick-up surface.

Consider a hemispherical surface acting in this capacity as shown in Fig. 7. Let it be oriented so that the axis of rotation of the hemisphere is on a line with the camera lens, the hemisphere being located at the position of the subject and directed toward the camera lens. A hemisphere is used because it represents as much of a sphere as a camera can see at one time, and its surfaces are arranged at all the possible angles that could be presented by a photographic subject to the camera. All illumination that would be photographically effective likewise would fall on the hemisphere. The hemisphere would receive and integrate all such illumination at its photographically effective value.

For example, suppose that a single source of illumination were located adjacent to the camera. This is the most efficient location for an illumination source, although it may be far from being the most artistic as to results. However, the light from this source goes directly to the subject and is reflected directly back with maximum efficiency. Other factors being equal, such a set-up would call for minimum exposure setting control.

Under these circumstances the meter with the hemispherical light pick-up, used as described, would receive illumination over the entire surface of the hemisphere (Fig. 8). This would result in a large needle deflection of the meter, and would dictate a minimum exposure control setting, which is exactly what the circumstances require.

Now suppose that the light-source were moved around through a 90-degree arc, so that its light would now strike the subject from the



FIG. 9. Effect of side light on collector.

side. Photographers have for many years had a rule of thumb to increase exposure controls by one  $f$ /stop for side lighting, which is the condition existing here.

The side light directly illuminates just about one-half of the hemisphere (Fig. 9). With only one-half of the hemisphere illuminated, the meter reading will be one-half that obtained in the previous case. Such a meter reading would indicate twice as great a setting for the exposure controls, which corresponds exactly with photographers' experience.

Similarly for all other angles of light approach to the subject, the hemisphere will pick up the portion of the illumination that will be effective upon the subject, and the meter will evaluate this illumination. Here then is the ideal instrument for measuring the photographic effectiveness of illumination incident on a photographic subject.

The device is inherently free from the influence of a number of factors that heretofore were at times sources of error. It is unaffected by relative proportions of high and low-reflectance areas in the subject, as demonstrated with the panels. It is unaffected by contrast of subject, effect of haze, distance of subject from camera, chromatic composition of subject, because it never "looks" at the subject, and is therefore independent of subject variations. Furthermore, it requires only one reading per scene for the great majority of all set-ups. It approaches the ideal of true instrumentation in that most of the factors that invite error due to dependence upon human judgment are eliminated from consideration.

The meter is universal in application, being equally effective for interior work and exteriors; and incandescent lights, arc lights, and daylight. It is suitable for both motion picture and still photography, and is excellent for both black-and-white film and natural-color film.

In the case of outdoor photography, where large distances may be involved but where the lighting is comparatively uniform over the area, it is not necessary to use the meter strictly at the subject's position. It may be used at any position where the lighting is comparable to that on the subject—right beside the camera if desired. The axis of the meter, however, should always be arranged parallel to the axis of the camera lens.

A prime feature of the proposed system of negative exposure control is that it corresponds to the natural action of the eye in adapta-

tion to the prevailing illumination on any scene. This feature makes it of great value in practical use, since picture making is based upon the manner in which the eye first sees the original subject and later the printed reproduction of the subject. Another important feature is that with negative exposures under precise control by this method it is possible to accomplish all normal printing within a very narrow range of printing exposure.

It is realized that there are several factors other than the proper measurement of light involved in negative exposure control. Some of these are variations in negative processing, variations in negative sensitivity and variations in the transmission of different lenses for a given lens aperture. In various quarters, however, attention is being paid to these variables and their effects are steadily being reduced.

In no phase of negative exposure control does general practice seem to be farther from scientific soundness than in that of measuring light. It is believed that the use of the system and device described here will do much toward establishing a more rational basis for negative exposure control, with consequent benefit to all concerned in the making of pictures.

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#### DISCUSSION

MR. NORWOOD: This meter is calibrated with an arbitrary scale which ties in with the Weston system of photo units. Full sunlight gives a reading of 450 on the scale. The meter is triple-range, in multiples of 10, the ranges being 0-10, 0-100, and 0-1000 units. It is sensitive down to a value of 0.05 unit. In terms of ft-candles, the range is 1.25 to 25,000.

To compare the range of this meter properly with the range of a brightness meter it is necessary to compute the equivalent values in candles per sq-ft encountered under given conditions of subject reflectance.

The reflected-light meter, which measures average brightness of the subject, would, if the subject were assumed to have an average reflectance of 13 per cent, require a range of 0.05 to 1040 candles per sq-ft in order to be equivalent in sensitivity.

Now consider the brightness meter which is used to measure both highlights and then dark spots, after which a mean is computed. Assume a reflectance of 2 per cent for dark spots and 80 per cent for highlights. The brightness meter would then require a range of 0.008 to 6370 candles per sq-ft in order to be equivalent in sensitivity to the illumination meter demonstrated here.

MR. SIMMONS: How is the sphere constructed?

MR. NORWOOD: It is made of a translucent, diffusing material, and is hollow. Behind it is the photoelectric element. Light striking the sphere is transmitted through to the element.

MR. SIMMONS: Would it be more feasible to build a spherical photoelectric surface?

MR. NORWOOD: Some sort of protective surface would be required. If glass were used it would probably reflect a good deal of the light.



## HOLLYWOOD'S LOW-TEMPERATURE SOUND-STAGE\*

R. VAN SLYKER\*\*

*Summary.*—The California Consumers Corporation of Los Angeles set aside one of its large ice-storage buildings to introduce to the studios a new method of making realistic snow scenes. The purpose of the ice-storage building was to furnish a low-temperature sound-stage, where water ice could be used for snow, and enable the cast's, breaths to become visible, as actually occurs in cold or wintry climates.

Snow is manufactured on the low-temperature sound-stage by means of specially constructed portable blowers, grinding 50-pound blocks of ice and expelling through suitable nozzle a fine, aerated snow, directed to the set where and when needed.

The introduction of Technicolor to the low-temperature sound-stage created many new problems in ventilation, due to the low temperature of the atmosphere and quantity of air movement needed to remove gases and smoke from the stage during shooting periods.

The unusual heat load requirements necessitated the construction of external bunker systems to augment the existing refrigeration for color production. This was accomplished by the combined use of water ice and ammonia refrigeration in these bunkers, giving a total refrigerating capacity of approximately 650 tons in the system to chill 64,000 cfm of fresh air to 20° F.

Cold, wintry scenes have necessarily been reproduced through the use of artificial means. The Arctic appearances and wintry effects have been improved by the addition of visible breath in order to give a needed reality to the snow scenes through the use of actual low-temperature settings of cold, frozen settings, *ice*, and realistic snow, giving a most stimulating effect to the members of the cast.

Snow used on the refrigerated stage is manufactured on the set through portable snow machines, taking fifty-pound blocks of ice and reducing them through a primary crusher, feeding this fine, crushed ice to the hopper of a special aerating blower, which, in turn, forces the aerated and pulverized ice through an extended flexible nozzle, forming a fine, light snow that is placeable in any quantity and amount as needed. These portable snow machines are not confined

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to the ice-house but on a great many occasions have been used on the Studio's own sound-stage or lots where the snow machine easily keeps up with the nominal ice meltage. The photographic value of this manufactured snow gives a natural and satisfactory effect, as the crystalline luster of nature's snow is captured by the camera.

The California Consumers Corporation of Los Angeles set aside one of its large ice-storage buildings in an effort to introduce to the Studios this new method in making realistic ice scenes. The conversion of the refrigerated ice-house into a usable sound-stage was easily accomplished. In structure the ice-house has a free area of 140 by 90 ft by 42 ft high, creating no unusual or acoustical problems, as the walls of the building were already insulated with 14 inches of shavings (for ice-storage requirements), giving the usually acceptable noise level of  $-30$  db, and the main problems to be overcome were those of heat *vs.* cold.

In determining the effect of temperatures for the operation of the ice-house without causing noticeable bodily discomfort to the cast and technical department, experimental findings show that a range of  $26^{\circ}$  to  $28^{\circ}$ F was sufficient to hold any amount of snow and ice on the sets and was not severe enough to cause discomfort except in isolated cases, allowing a margin of  $4^{\circ}$  to  $6^{\circ}$  rise before approximating the melting point of the ice. Common colds and catarrhal discharges were less prevalent in unit groups than found elsewhere during the cast's stay in the refrigerated stage. The bodily temperature changes were modified through the installation of a vestibule maintained at an intermediate temperature in order to avoid abrupt temperature changes. The serving of ample heated liquids greatly reduced any discomforts the low temperature may have caused to members of the company.

During the operation of this stage, operating factors governing the refrigerated stage are entirely unlike those of any other sound-stage, due to the extreme low operating temperature required to preserve the ice and snow settings and to maintain the set temperature so as to gain the visibility of the cast's breath. Among other operating factors is the needed 25 to 30 tons of refrigeration required to offset the heat transfer of the walls.

The heat load based on lamp amperage for black-and-white photography ranges from 1500 to 4000 amperes, necessitating a minimum of 185 tons of refrigeration to offset this particular heat load, which may be readily calculated to the following formula:

$$\frac{3.42 \text{ BTU} = 1 \text{ Watt} \times 1000 \text{ W.} - 5619 \text{ BTU}}{\text{Amperes} \times \text{BTU} = \text{Heat Load} \div 333,000}$$
$$\frac{\text{Heat Load} \times 3420 \text{ BTU}}{12,000 \text{ M.P.P.T.} - \text{Load Inter. of Ref.}}$$

One serious factor in the operation of the refrigerated stage is that of replacing the exhausted, vitiated, and other foul air from the room with chilled fresh air, in order to prevent the warming of the prevailing interior temperature through the introduction of warm, outside air. This was handled by the installation of a large air-precooling bunker<sup>6</sup> system consisting of approximately 6000 feet of 2-inch ammonia pipe, in addition to the existing refrigeration system of nearly 4 miles of ammonia piping installed on the ceiling of the stage.

The bunker system equipment consists of a 25,000-cfm positive pressure blower passing the warm room air, together with approximately 30 per cent of fresh, outside air, through the coils, and exhausting the cooler air into the stage at approximately 1 inch of pressure, the foul air in turn being expelled through a series of suitable, controllable exhaust hatches located in the stage ceiling some 42 feet from the floor.

After tests were made of this initial air flow during actual operation, it was decided to increase the air flow over the ceiling coils by the installation of four utility air-screw fans recirculating the warmer air near the ceiling, giving an additional air circulation of some 16,000 cfm of free air across the main ceiling refrigerating coils.

The misty vapor accompanying ice or snow scenes is greatly eliminated on the stage by virtue of this large, cold, dry air flow. The vapor or fog is in reality water vapor released by the ice when the directed rays of the lamps strike it. After flowing the damp, vapor-laden air over the cooling coils, it precipitates a large percentage of the air-borne moisture. The slight vapor released by the ice is thus absorbed and a consequent reduction of the total vapor in the stage atmosphere occurs.

With the introduction of Technicolor photography to the ice-house, the large increase in lighting requirements over black-and-white photography caused many problems in adapting the refrigerated stage to handle the increased heat and gas content of the air generated by the numerous carbon arc lights required for the Technicolor process. Heretofore recirculation of 70 per cent of the interior air was possible, due to the prevalence of incandescent lighting used in



black-and-white photography. This recirculation could not be continued due to the high gaseous content of the air through the use of nearly all arc lights. The increased gaseous volume of air required the addition of approximately 48,000 cfm of chilled air in order properly to ventilate the stage and maintain the correct dry and wet bulb temperature conditions.

In determining a method of ventilating the stage during Technicolor shooting, it was decided to enter air at approximately 20°F at floor level and allow the heated air to rise and escape through the ceiling exhaust hatches. During the calculation of the required refrigeration tonnage to maintain the stage floor level at approximately 20°F during the filming of Technicolor productions, it was found that the refrigeration plant equipment supplying the stage could handle an additional heat load of only 25 per cent, as during the summer season of the year the remainder of the plant refrigeration equipment was needed for ice manufacture and cold-storage facilities.

The problem was additionally complicated due to the present cold-storage plant set-up, as the various storage departments were on different suction pressures; also due to the unusually high gas content of the stage atmosphere it was essential that only clean, fresh air should be used on the stage.

Again, due to the short time available for equipment installation, it was not deemed feasible to try to install additional compressor capacity, or to couple a brine-cooling system to the ice-manufacturing section of the plant. Further complications were those of obtaining proper air circulation on the stage due to the type of construction and location of the set. Adequate air circulation was further hindered by a large cyclorama hanging from the walls of the stage.

The total connected electrical load for this Technicolor production was approximately 17,000 amperes, which alone would have required 540 tons of refrigeration on the stage had this connected load been used in its entirety.

Fortunately, the total connected lamp load of a set is almost never used at one time, and the maximum recorded load on this production was approximately 9600 amperes. Again, it was noted that the average burning period of the lamps in a black-and-white production is approximately 20 to 30 minutes out of each hour. With Technicolor the general average is increased to 30 or 40 minutes in each hour, and we were able to eliminate approximately 50 per cent of this heat load by placing many of the lamp resistances in the attic immediately over



the stage sets, permitting the attendant resistance cables to exit through the ceiling exhaust hatches.

By taking every possible advantage, we were able to reduce the total available heat load of the lamps to approximately 140 tons of refrigeration. While this figure may seem low, it must be remembered that the resistances of the lamps account for approximately 50 per cent of the total ampere heat load input. Again, in order to obtain the required air change in this building, and from the experience of the Studios on stages of identical size, it would require a total of 64,000 cfm of chilled fresh air to do so. This excessively high volume of fresh air in itself requires a refrigeration capacity of over 500 tons to reduce the normal wet-bulb temperature of approximately 70° to 20°F. The existing temperature on the exterior of the building during this particular time was approximately 83° to 90°F (in the shade).

The cold air supplies were divided so as to be handled by three separate blower systems, and these were of slightly different sizes in order to achieve a desirable flexibility.

The installation of two blowers of 18,000 cfm each and one blower of 28,000 cfm gave the required total volume of 64,000 cfm. The refrigeration load was divided into two divisions to make use of the available refrigeration plant capacity of 200 tons of refrigeration and to apply the required refrigeration difference through the use of wet ice bunkers.

The division of the load in this manner worked out satisfactorily, as it was possible through the use of wet ice bunkers to reduce the temperature of the incoming air to approximately 40°F dry-bulb and 39°F wet-bulb, as had been proved possible by previous experimentation. This would account for nearly 450 tons of the 650 tons' total air load refrigeration so that a final 200 tons were left for ammonia refrigeration. This permitted the 200 tons' available capacity of the refrigeration plant to reduce the air to the required floor temperature of 20°F through the use of a series of finned coils. Having settled the disposition of refrigeration loadings, construction was started on three separate bunkers to house the blowers and cooling equipment, including in these bunkers a capacity of 450 tons of wet ice for the three primary stages. The hourly ice usage was 450, plus twenty-four, equalling 18.75 tons of melt per hour.

Dividing this ice consumption between the three ice bunkers according to air volume:

*Bunker A*—to be connected with existing 50-ton straight pipe coil is as follows:

$$18.75 \text{ tons of ice} - \text{total} \times \frac{18,000 \text{ cfm} - \text{bunker}}{64,000 \text{ cfm} - \text{total}} = 5.3 \text{ tons of ice per hour.}$$

*Bunker B*—to be connected to 28,000-cfm fan and center of building:

$$18.75 \text{ tons of ice} - \text{total} \times \frac{28,000 \text{ cfm} - \text{bunker}}{64,000 \text{ cfm} - \text{total}} = 8.2 \text{ tons of ice per hour.}$$

*Bunker C*—to be connected to 18,000-cfm fan and end of building:

$$18.75 \text{ tons of ice} - \text{total} \times \frac{18,000 \text{ cfm} - \text{bunker}}{64,000 \text{ cfm} - \text{total}} = 5.3 \text{ tons of ice per hour.}$$

The three ice bunkers were set up as vertical chambers, which were loaded from the top with ice broken in about 25-pound pieces, and through which the outside air was drawn vertically from top to bottom. This arrangement allowed an even spread of ice across the area where the air contacted the ice, and permitted no voids to occur as would have happened if air had been drawn through horizontally and the ice had melted down to the lower side of the cooling area. Also this arrangement allowed the loading to be done through the same opening through which the air entered, so that loading could be done while the system was in operation. The ice bunkers then consisted of vertical shafts, with open tops, placed alongside the evaporator chambers and opening along the bottom of the adjoining side, so as to allow the air to leave the bottom of the adjoining side and the bottom of the shaft, and enter the evaporator chamber horizontally.

Supporting the column of ice was a grille set at the level of the top of the evaporator plenum. The grille at this level permitted the air to be drawn completely through the ice while travelling in the same direction, so that the ice was melted evenly and pockets were avoided. The required height and area of the shaft were based upon (1) the average density of the ice, in 25-pound blocks; (2) the optimum velocity of air through ice for transfer of cooling, but without excessive resistance and possible noise; (3) the necessary height of ice column to produce the required temperature reduction, but without excessive resistance.

Through previous experiment, it was found that one cubic-foot of the scored ice as broken into 25-pound blocks averaged about 27 pounds. It was also found that the effective open area for air travel

through the shaft was approximately one-half of the total area, so that the effective velocity through the ice was approximately twice the velocity of the shaft when empty. Also, it had been proved in an experimental tower that 8 feet of ice column were necessary to reduce air at  $80^{\circ}$  to  $40^{\circ}$ . Based on these factors, the average dimensions of these three bunkers were  $8 \times 8$  feet in area and 16 feet in height.

The coils for *B* bunker were four four-row sections 72 inches  $\times$  24 inches with three fins per inch, to give a tonnage of 92, with a velocity of 683 fpm. The coils for *C* bunker were two four-row sections 72 inches  $\times$  30 inches with three fins per inch, to give a tonnage of 58, with a velocity of 600 fpm. The nozzles for the brine spray system to keep the *B* coil defrosted were Binks No. 11 Rotojets, with a  $1/2$ -inch pipe connection and  $3/8$ -inch orifice, and with a capacity of 4 gpm at a pressure of 10 pounds per square-inch. Twenty of these were used, arranged four rows wide by five high, and set approximately 12 inches from the face of the coil. Twelve of these same nozzles set four wide by three high were used for *C* coil.

The brine pumps used for the defrosting were 80 gpm for the *B* coil and 50 gpm for the *C* coil, with each providing for a head of 40 feet.

Each ice bunker was constructed to carry sufficient volume of ice for approximately a  $2\frac{1}{2}$ -hour run so that one loading crew could alternately load the bunkers and, allowing 45 minutes for loading, could go continuously from bunker to bunker.

Each bunker had the following capacity:

Bunker <i>A</i> —2.5 hours $\times$ 5.3 tons/hour	= 13 tons of ice capacity
<i>B</i> —2.5 hours $\times$ 8.2 tons/hour	= 20 tons of ice capacity
<i>C</i> —2.5 hours $\times$ 5.3 tons/hour	= 13 tons of ice capacity

These three ice bunkers were set up in vertical chambers, which were loaded from the top with ice broken into about 25-pound pieces.

The resulting performance of this new refrigeration equipment can be seen from the following chart taken during one of the shooting days. These readings, which were taken under typical conditions of weather and lighting load, were made at 2:00 P. M., August 2, 1939. The maximum lighting load used that day was 8500 amperes:

Outside temperature	$83^{\circ}\text{F}$
Temperature of air off ice, Bunkers <i>A</i> , <i>B</i> , and <i>C</i>	$40^{\circ}$
Temperature of air off coil, Bunker <i>A</i>	$20^{\circ}$

<i>B</i>	21°
<i>C</i>	19½°
Room temperature, before shooting—2:00 P. M.	21°
Room temperature, after shooting—2:30 P. M.	23°
Temperature under light parallels	28°
Temperature on light parallels 28 ft from floor	34°
Temperature in exhaust outlets from attic	74°
Average ice usage	16 tons per hour
Ammonia suction pressure on finned coils	5 lb/sq-in. gage
Ammonia suction temperature on finned coils	17°F
Average fresh air usage	62,500 cfm



## THEORY VS. PRACTICE

F. H. RICHARDSON\*

*Summary.*—A brief discussion of the desirable qualifications for projectionists, both as to theoretical and practical training. Reference is made to a system of licensing and examination in the Province of Alberta, Canada, as contrasted with unsatisfactory conditions prevailing in a number of parts of the United States.

Some will doubtless regard what is said here as merely a re-discussion of an old story, namely, the importance and necessity for the further practical and technical education of projectionists in their art. Granting that, technical members of our Society and the engineering departments of equipment manufacturers and producing companies must in addition recognize the extent to which their work may be nullified by the failure of many theaters to employ projectionists able to supply adequate evidence of capability in handling the equipment and products placed into their charge.

Such failure on the part of the theaters has worked considerable harm. Replacement of projectionists lacking in technical knowledge and skill by others well versed in the technique and practice of projection would produce great improvement in results and economy of equipment and operation. The existing situation seriously discredits the work of the scientists and engineers in the eyes of the theater patrons as well, and the author feels that the Society has not taken sufficient cognizance of the fact. This is not a blanket charge against all projectionists. There is a constantly increasing number who, having sensed the importance of their work, are studying its technic and practice to such good purpose that they are able to do full justice to the apparatus and productions handled by them. Such men are a credit to their profession. On the other hand, there are still some men holding positions as theater projectionists who are equipped with little if any technical knowledge; who have little understanding of the forces they are called upon to handle; and who in many instances are possessed of mediocre mechanical skill.

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\* Quigley Publishing Co., New York, N. Y.

Such a state is unfair to the technician, the engineer, the manufacturer, the producer, the exhibitor himself, and to the theater-going public, which in the final analysis supports the entire industry. The theater patron is unable to locate the source of a fault in projection and makes no effort to do so, but it is generally known that he always attributes the fault to the equipment or the film.

A few efforts have been made to rectify the situation, or at least to ameliorate it. As an example, we may cite the regulations of the Province of Alberta, Canada, recently promulgated not only for the purpose of reducing possible fire and other hazards in motion picture theaters, but to improve the performance as well. Alberta requires one year of service as a licensed apprentice projectionist before a final license can be granted, with the exception that projectionists from other places should be able to convince the authorities of their competency and may receive their licenses without serving the apprenticeships. During the period of apprenticeship the applicant must have at least 300 hours of actual service in a theater projection room under the supervision of a first-class projectionist. During all this time he is not permitted to assume charge of projection. Violation of this regulation may result in the loss of a license of the licensed projectionist supposed to be in charge. During the apprenticeship, quarterly examinations are held to ascertain the rate of progress. At the end of the year, after 300 or more hours of actual service, the apprentice may take his examination. If the result is satisfactory, a third-class license will be awarded permitting him to act as projectionist in a theater containing 350 seats or less. If the theater has more than one projector, a second licensed man must be constantly on duty. At the end of a year of service under the third-class license the man may appear again for examination. If the result is again satisfactory, he will be awarded a second-class license permitting him to take charge of projection in theaters of 500 seats or less; and, again, if there is a second projector, there must be a second licensed projectionist to assist him. During this year, 500 hours or more of actual projection work is required. At the end of the year of the second-class service the man is reexamined, and if found competent will finally receive a first-class license.

It may be observed that Alberta takes its license laws very seriously. The laws specify, in addition, that certain subjects be included in the examinations for each class of license, and it may

safely be assumed that the holder of an Alberta first-class license is a thoroughly competent projectionist.

All Canadian provinces proceed more or less along the same general ideas, and definite assurance must be provided at each stage that actual progress in technical knowledge and experience has been made before the next class of license may be granted, and the learning and experience must be gained under the tutelage of a first-class licensed projectionist.

On the other hand, let us look at the situation in one of the states of our own country, which, for obvious reasons, will be unnamed. Apparently the state recognizes that some protection is due its citizens against the employment of incompetent projectionists, but aside from the recognition of general safety practices in relation to fire hazards in public meeting places, little is required in the way of actual competence in projection. Regulations are extremely vague, and only a "practical" examination is required. No attempt is made to be sure that even the examiner himself is competent to give an examination on theater projection, and it is left entirely to the examiner as to what shall constitute a "practical" examination. But that is not all. In many cities, towns, and villages of the country, there is no protection at all other than by law. In many instances, any school boy with no technical knowledge or practical experience may take charge of projection in a theater, and not only abuse the equipment and film, but jeopardize the audience and give a "black eye" to the entire industry.

The lack of laws specifying anything further than "practical" examinations in first-class cities lays the entire system open to political and other abuses, wherein it might be possible for examiners to reduce the meaning of the term "practical" to very low values at the request of political "higher-ups."

One state at one time made provision for apprenticeship prior to examination for the final license, but the law was later thrown out because it contained no clause permitting the licensing, without apprenticeship, of projectionists from other states who could prove thorough competency.

There seems to be wide opposition to the idea of apprenticeship, chiefly on the grounds that there may be in some parts of the country more projectionists available than positions. This objection might be overcome by a requirement that all projectionists now holding licenses be reexamined, under a really competent examiner.



The question arises as to what the Society of Motion Picture Engineers can do in the matter. It would seem that the Projection Practice Sub-Committee, of our Theater Engineering Committee, could examine the situation and recommend to the states a set of regulations that might be used in examining applicants for projectionists' licenses. They might also prepare a list of subjects upon which such applicants should be examined, and determine the scope of knowledge and experience that the applicants should have before being permitted licenses. Suitable provisions could be included in such recommendations for the apprenticeship which has been proposed here.



## PIONEERING IN THE TALKING PICTURE\*

W. E. THEISEN\*\*

The history of the sound picture dates back to 1877, the year of Edison's announcement of the phonograph, which brought the realization that the human voice could be mechanically reproduced. Between that time and the time of the successful demonstration of the motion picture in 1889 there were a number of scientific dreamers who hoped to make talking photographs. They tried to synchronize the human voice or music to slide photographs; and with the advent of the "living pictures" these experimenters tried to make of them talking motion pictures.

Wordsworth Donisthorpe was, according to present records, the first to suggest and experiment with the idea of talking photographs. He wrote a letter to the editor of *Nature* which was published in the issue of January 24, 1878, under the title "Talking Photographs." In it he said:

"By combining the phonograph with the kinesiograph I will undertake not only to produce talking pictures of Mr. Gladstone which, with motionless lips and unchanged expression, shall positively recite his latest anti-Turkish speech in his own voice and tone. Not only this, but the life-size photograph itself shall move and gesticulate precisely as he did when making the speech, the words and gestures corresponding as in real life."

He adds further, in effect, that he took his photographs at intervals of half or quarter seconds, with an exposure of an eighth second. The finished pictures were mounted upon a long paper band.

His kinesiograph, or camera, was so arranged that as each exposed glass plate dropped out of the way, it was replaced by the next plate which was directly behind.

The phrase, "with motionless lips and unchanged expression," is evidently a reference to the fact that Donisthorpe recorded only a

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\*Presented at the 1934 Spring Meeting at Atlantic City, N. J.; revised February, 1937; January, 1941.

\*\*Curator, Motion Picture Division, Los Angeles Museum, Los Angeles, Calif.

series of static poses, which resulted in the loss of facial expression and intermediate progressive movement. Because he could photograph only at the rate of two to four pictures a second, as compared with the present twenty-four each second, expression and action conforming to the sound record were lacking, as several words would be spoken while each still picture was viewed.

Since the Edison phonograph at that time was far from perfect, very little came of Donisthorpe's experiments. One of these early Edison phonographs with soft wax records in the possession of the author corroborates the phrase, "the wee small voice," by which the phonograph was then known. The words are barely distinguishable—if they be known in advance—and the tunes are only approximations of the intended tunes.

#### EARLY PHOTOGRAPHIC SOUND RECORDS

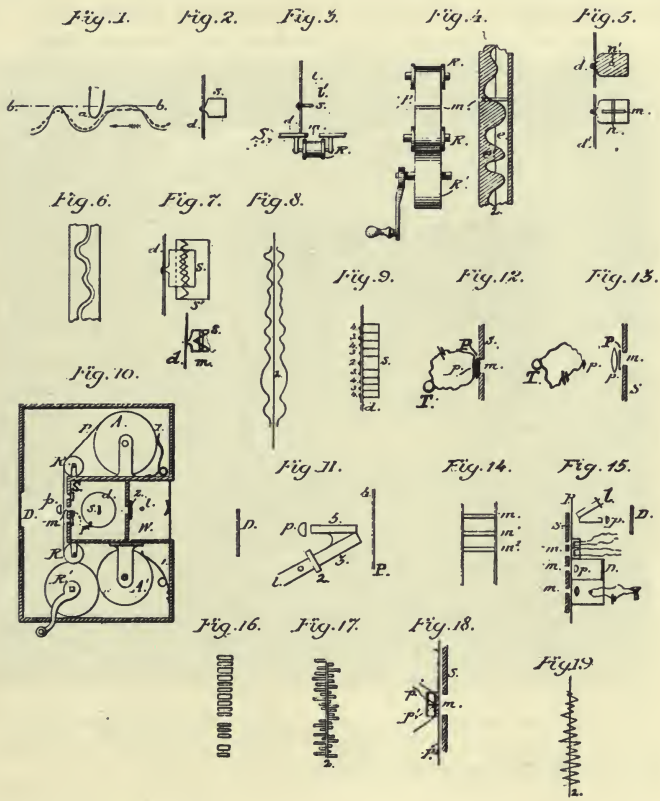
The first two men who concerned themselves with photographically recording sound were Czmark of Vienna, who, in 1862, photographed the vocal cords in action, and Alexander Blake of Brown University, who, in 1878, conducted a series of experiments in photographing the vibrations of a pencil of light from a mirror attached to a microphone diaphragm. In Blake's experiments the photographic plate was kept in motion by a clockwork mechanism.

Charles E. Fritts applied for a United States Patent on October 22, 1880, which covered methods of recording sound photographically. In the claims of his patent are specifications for shutters, and various optical systems are covered for focusing the shutter or slit records, which were made on a long photographic band.

Fritts suggested that the sound might be reproduced by causing a beam of light or other radiant energy passing through the moving record to fall upon bars of selenium, which would respond in such a way as to regulate an electric current and thus operate a diaphragm. He (and many others, subsequently) tried to reproduce sound by passing a light beam through a moving photographic sound record, thus permitting light of varying intensity to pass to the selenium.

The brief of the Fritts' patent—twenty-six pages long—covers the basic elements of sound recording as we now know them, and shows a deep insight into the problems that have presented themselves subsequently. A system of amplification is covered, various types of slits and sound-tracks (or "patterns," as he calls them), and many other features. This amazing patent was granted thirty-six years

C. E. FRITTS, DEC'D.  
J. H. FRITTS, ADMINISTRATRIX.  
RECORDING AND REPRODUCTION OF PULSATIONS OR VARIATIONS IN SOUNDS AND OTHER PHENOMENA.  
APPLICATION FILED OCT. 22, 1880.  
1,203,190.  
Patented Oct. 31, 1916.  
4 SHEETS—SHEET 1.



Witnesses:  
*C. L. Wilbur*  
*F. Gerrell*

Inventor:  
*Charles E. Fritts*

FIG. 1. Section of U. S. Patent by C. E. Fritts.



after its application, on October 31, 1916, as number 1,203,190\* (Fig. 1).

Georges Demeny introduced his *chronophotophone*, in October, 1893, although he had demonstrated it earlier.<sup>1,2</sup> It was a device that synchronized a photographic record and slide photographs which were mounted around the periphery of a glass disk. In the



FIG. 2. Projection room (about 1894), showing phonograph attached to kinetoscope for synchronization of sound and picture. (*Century Magazine*, 18, 207, 1894.)

slides were attempts to portray motion that had been photographed in the "Photographic Gun" which Demeny had devised about ten years earlier.<sup>3</sup>

#### EXPERIMENTS OF EDISON AND DICKSON

In the meantime Edison had approached the problem of giving eyes to his phonograph. In *The History of the Kinetoscope, Kinetograph, Kinetograph, Kinetograph*

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\*In this patent are descriptions of a string galvanometer, push-pull recorder, narrow slit, rubber roller for damping the recording drum, record wear which destroys the high frequencies, and so forth.



## PICTURE SONGS

We have at last succeeded in perfectly synchronizing music and moving pictures. The following scenes are very carefully chosen to fit the words and the songs, which have been especially composed for these pictures.

### • LOVE AND WAR.

Uncholerick.

The above is an illustrated song telling the story of a hero who leaves for the war as a private, is promoted to the rank of captain for bravery in service, meets the girl of his choice, who is a Red Cross nurse on the field, and finally returns home triumphantly as an officer to the father and mother to whom he bade good bye as a private. Length 200 feet, complete with words of song and music. \$15.00

### • THE ASTOR TRAMP.

Unchurn.

A side-splitting subject, showing the mistaken tramp's arrival at the Wm. Waldorf Astor mansion and being discovered comfortably asleep in bed, by the lady of the house. Length 100 feet, complete with words of song and music. \$20.00  
Without music. (Unchurch) \$15.00

Complete Set, 22 subjects, about 1,950 feet, \$400.00

### OPERA OF MARTHA.

Unbeflecht.

The Second Act of this beautiful opera. Consists of five scenes, about 1,300 feet in length. 1. Duet outside the Inn. 2. Quartette inside the Inn. 3. Spinning Wheel Chorus. 4. Martha singing "Last Rose of Summer." 5. Good Night Quartette. This film shows a quartette of well-known opera singers acting and singing their parts in this ever popular opera. The subjects are taken with the greatest care and the films manufactured by the Edison Manufacturing Company.

Managers can arrange to produce this exhibition throughout the country, and can obtain a quartette of church singers to remain behind the scenes and sing the parts and produce a remarkably fine entertainment, besides giving a local interest to the same by utilizing local talent. If it is desired to do so, however, the quartette can be engaged to travel with the exhibition.

Other operas and plays in preparation.

Complete Set, 5 scenes, about 1,300 feet, \$320.00.

**Special Notice.** These films are taken under license of Thomas A. Edison, whose patents cover moving photographic films.

FIG. 3. Portion of a page in an Edison motion picture catalog, dated March, 1900.

*graph, and Kinetophonograph*, written by W. K. Laurie Dickson and published in 1895, is reproduced in Edison's handwriting: "In the year 1887 the idea occurred to me that it was possible to devise an instrument which would do for the eye what the phonograph does for the ear, and that by a combination of the two all motion and

sound could be recorded and reproduced simultaneously." That briefly sums up Edison's purpose for the motion picture. All his early experiments to achieve this purpose were closely patterned after the phonograph.<sup>4</sup>

Dickson's history interestingly tells of a studio room constructed at the Edison plant at Orange, N. J., for the purpose of creating motion pictures, and a sketch of the interior of this studio shows a camera and phonograph coupled together for taking a "talkie," (Fig. 2). The *Kinetophone*—Edison's sound motion picture device—was commercially introduced about the same time as his silent *kinetoscope*, or "peep-show," was put into the "peep-show parlors." The first of these parlors was opened by the Holland Brothers on April 14, 1894, at 1155 Broadway, New York, N. Y.

Shortly thereafter, many parlors installed *kinetophones*, in which patrons, after putting a coin in the slot, could peer through an eyepiece at moving pictures and, at the same time, by means of ear-tubes somewhat similar to the physician's stethoscope, listen to a sound accompaniment. The early catalogues published by Edison listing his motion pictures carried a list of orchestral records that had been specially recorded for playing with the pictures.

One of these catalogs of March, 1900, on display at the Los Angeles Museum, itemizes several pictures that could be purchased with or without sound records (Fig. 3). An explanatory note in this catalogue states, "We have at last succeeded in perfectly synchronizing music and moving pictures. The following scenes are carefully chosen to fit the words and songs, which have been especially composed for the picture." The price for a 200-ft. picture, *Love and War*, was \$45.

The kinetophones were not successful, but Edison continued to toy with the idea. In 1910 he introduced another system designed to show sound pictures in the comparatively large film theaters that had, in the meantime, made their appearance. This system consisted of a phonograph placed upon the stage, run by a long wire belt connected to a projector at the rear of the theater. It enjoyed no extensive use beyond approximately a four-month run at the B. F. Keith Theater in New York.

The idea of the talking picture was firmly established. It seemed logically possible to the first experimenters that the phonograph could be synchronized to a projector. Among the first specifications of means for achieving synchronization, besides those already men-

tioned, was that of George W. Brown, who was granted a United States patent on February 9, 1897. Two years later, on July 31st, a German patent was granted to L. A. Berthon, C. F. Dussaud, and G. F. Jaubert, in which were specifications for synchronizing a projector and phonograph.

Valdemar Poulsen patented a novel sound-recording system in Germany on April 21, 1900. He passed a steel ribbon between two electromagnets energized by a current that was modulated in a microphone. When the diaphragm of the microphone was bombarded by sound, the fluctuations were produced in an associated electric circuit which in turn induced a magnetic pattern in the steel ribbon.

In the *Scientific American* of July 29, 1901, Ernst Rühmer announced a method of recording a sound-track photographically upon motion picture film. It was a fluctuating arc device which he called the *photographophone*.<sup>5,6</sup>

#### THE WORK OF LEON GAUMONT

The British Patent Journals record a number of patents granted to Leon Gaumont and H. H. Lake in collaboration during 1901-03, dealing with various systems for synchronizing phonographs and projectors by means of gears or brushes on the armatures of driving motors. The patents specify loud speaker systems, and suggest the use of loud speakers behind the screen. The speakers were intended to be carried about, following the moving images upon the screen.

Gaumont's first public demonstration was given on November 7, 1902, at the Société Française de Photographie, when he presented, among other things, his own talking portrait. The system used for this demonstration consisted of a specially designed gramophone from which a projector was operated by means of a flexible shaft. Very shortly this flexible shaft was replaced by an electrical connection. In order to start the phonograph and projector simultaneously, a "current distributor" was attached to the phonograph shaft to keep the speed of the two synchronous and uniform.

In 1903, the system was shown at the Musée Grevin, and a little later at the Theatre Du Gymnass, under the name *Phonoscenes*. Nothing much was heard of the system until 1910, when a talking picture of Professor D'Arsonval was presented to the Academie des Sciences on December 27th. It was brought to this country in 1913, during which year it was exhibited at the 39th Street Theater, New



York, on June 5th-7th. In the meantime the Gaumont *Film-Parlant* had been showing nightly at the Gaumont Palace in Paris.<sup>7,8,9,10</sup> The Gaumont sound apparatus was known as the *Chronophone*. Subsequently to 1926, Gaumont worked with the Petersen-Poulsen sound-film system.<sup>11</sup>

#### OTHER METHODS OF SYNCHRONIZING PICTURES AND PHONOGRAPHS

During 1903-04 Oscar Messter was granted several German patents on methods of synchronizing phonographs and projectors.<sup>12</sup> One claim granted to him in an English patent dated October 19, 1903, specifies a synchronizing mark to serve as a starting guide. Messter's system, known as the *auxtephone*, utilized compressed air in the speaker for amplifying the sound. It is said that by means of air-compression amplifiers, Messter surmounted one of the chief difficulties of the sound picture pioneers, namely, sufficient volume. It would seem, however, that Gaumont had sufficient volume in his sound pictures, because, in 1913, he is said to have successfully shown talking pictures for a time at the Gaumont Palace, previously the Hippodrome, to audiences of 4000 persons.

In 1904, the *cameraphone*, introduced in New York by James Whitman, enjoyed extensive commercial success over its contemporaries. A flexible-shaft arrangement for maintaining synchronism between the phonograph and the projector was patented in France in 1907 by Georges Pomarede.<sup>13</sup>

Among others to develop and patent phonographic talking picture systems in the next few years were W. C. Jeapes,<sup>14</sup> who applied for a patent in 1909 on his *cinetophone*, and Cecil Hepworth,<sup>15</sup> who introduced the *vivaphone* at about the same time in England. These two English experimenters devised an interesting though somewhat impracticable method of synchronization. The cinetophone, brought out commercially by the Warwick Trading Company, had a rotating pointer, driven by the gramophone motor, on the front of the gramophone cabinet, and the progression of the sound record could be followed as the pointer turned past a series of green lights on a dial. To maintain synchronism of the sound and the picture, the motion of the pointer on the gramophone was made to correspond to that of a second pointer photographed on the film. The projectionist contrived to keep the two in step by manually varying the speed of the projector.



Likewise the vivaphone had a pointer arrangement for synchronization. The pointers were actuated by a pawl and two electromagnets, one each for the projector and the gramophone. The system was adaptable to any projector.<sup>16</sup>

A somewhat similar system was devised by Thomassin, with the difference that the pointer was held stationary by an electromagnetic escapement, and any lack of synchronism was indicated by movement of the pointer.<sup>17</sup>

E. H. Amet was granted numerous United States patents during 1912-18 on a system called *Audo-Moto-Phone*.<sup>18</sup> These patents



FIG. 4. E. H. Amet and Mrs. Amet, with their disk sound and picture recording equipment—1912.

covered electrical pick-up methods of recording, and sound devices in a variety of forms. That Amet was particularly interested in talking pictures may be judged from the fact that the SMPE Historical Collection at the Los Angeles Museum includes about thirty-six different experimental devices made by him. Newspaper items from various California towns where Amet's sound pictures were shown were profuse in their praise. During 1914-16, Amet developed a "balanced" microphone, which was patented.<sup>19</sup>

For synchronizing, Amet relied upon a connecting shaft between the projector or camera and the phonograph (Fig. 4). His "amplifi-

cation" through the theater was effected by "loud speakers" set at various vantage points.

In order to give an idea of the many ramifications of the efforts made to realize the sound picture, mention must be made of the work of Katherina von Madelar, who was granted her first sound patent in 1916, on a system of recording a sound-track by means of an electrically heated needle.<sup>20</sup>

The needle was attached to a microphone diaphragm, which, upon being caused to vibrate by the impinging sound-waves, caused the heated needle to cut a waving line in a celluloid ribbon. Another novel von Madelar system involved a rotating cutter, which turned in contact with the edge of the film. The cutter received the sound vibrations from the microphone diaphragm, and recorded them as a jaggedly cut pattern upon the film edge. The system was called the *projectophone*.

Another system of synchronizing the cinematograph and the gramophone was devised by William H. Bristol, and termed the *Bristolophone*. It was patented in the United States in 1917, and was used to some extent after the advent of the talkies.<sup>21</sup>

There were many, many others. An investigation of the patent records indicates that the researches undertaken to create the talking picture were as diverse as were the experimenters, and that often the dreams of the experimenters led them far afield. In England alone, for the years 1908-09, twenty-seven patents were granted. These many undertakings were not without value, however; the practical and the impractical researches both have aided in accumulating the knowledge that has led to the perfection of the talking picture.

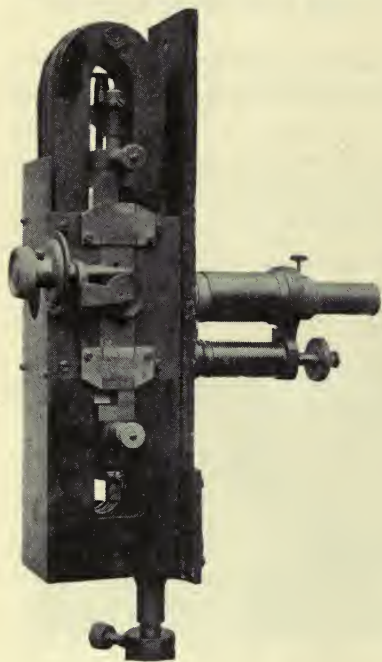


FIG. 5. Lauste's string recorder; used by Lauste about 1910-11 for recording sound-on-film.

## CONTRIBUTIONS OF E. A. LAUSTE

In the meantime there were parallel developments by other men who tried to record the sound on the photographic emulsion. In tracing the history of the sound-film, the work of Eugene A. Lauste is generally regarded as very significant. Lauste made his first recorder

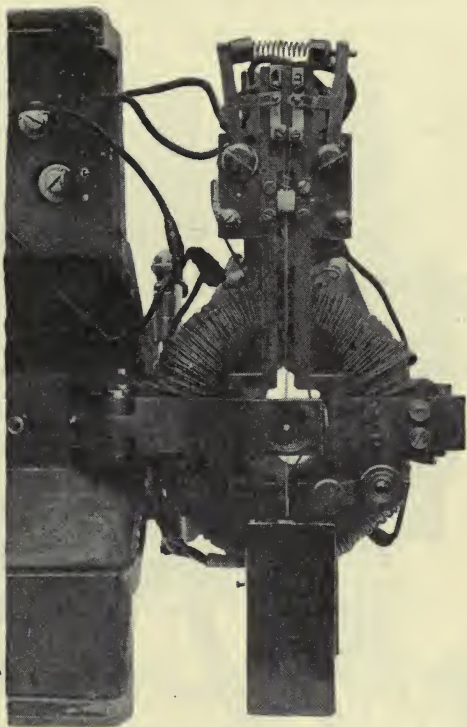


FIG. 6. Lauste's string recorder (open), showing diamagnetic double vibrating wire (1911-13).

in 1904, along the lines of earlier apparatus made by both Fritts and Blake. It consisted of a box containing a slit, or narrow aperture, through which a light-beam was directed by a mirror attached to a microphone diaphragm. Movements of the diaphragm caused by the sound vibrations produced movements of the mirror and the light-beam, the vibrations being recorded upon motion picture film.

Lauste continued to improve and to elaborate his devices in an attempt to record the picture and the sound upon the same film.



On August 11, 1906, Lauste, in collaboration with Robert T. Haines, an Australian experimenter, and John St. Vincent Pletts, a British engineer, applied jointly for a British patent for "A New and Improved Method of and Means for Simultaneously Recording and Reproducing Movements and Sounds." British patent<sup>22</sup> was granted them on February 11, 1907.\*

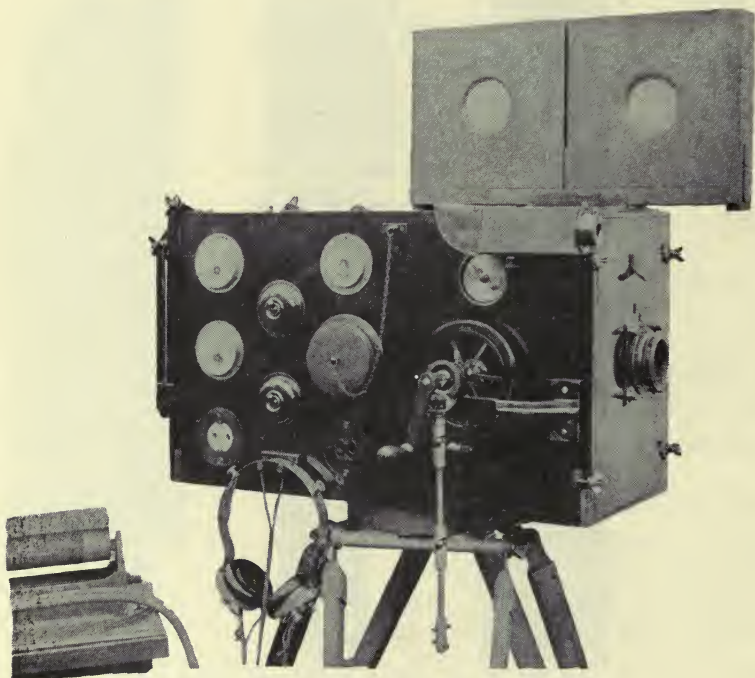


FIG. 7. Lauste's "sound and scene" camera (1912-14).

There is a question of just how much assistance the collaborators gave Lauste. Some publications have given them extensive credit, while others hold that Lauste had disclosed and conceived the primary factors prior to his association with them. Undoubtedly they offered some advisory assistance besides their financial aid.<sup>23, 24, 25, 26</sup>

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\*The patent describes a vibrating galvanometer, oscillograph, light-valve, and a projector having a loop between the sound and picture gates.



Lauste continued his experiments with recorders of various types until 1910, when he hit upon the idea of using a string galvanometer (Figs. 5 and 6). The galvanometer recorder consisted of a mirror attached to a silicon bronze wire stretched between the poles of two magnets. As current from the microphone passes through the

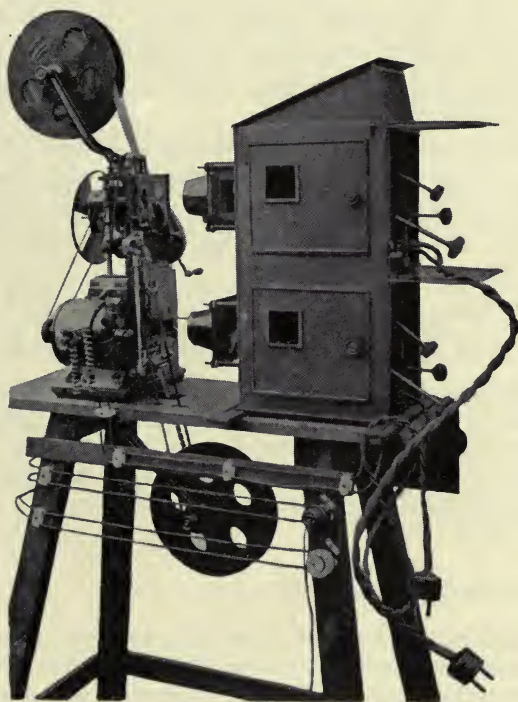


FIG. 8. Lauste's "sound and scene" projector—1912. The lower lamp house was used to illuminate the sound-track. Film projector is the old "Pathé Professional." This apparatus was first used by Lauste in 1911.

electromagnets, the fluctuating magnetic field caused the string and mirror to vibrate accordingly. Movement of the mirror in a beam of light traced the sound pattern photographically upon motion picture film. Within a year Lauste had made a comparatively successful sound and picture record. The sound record was of the variable-width type and occupied half the width of the film; the picture utilized the other half (Figs. 7 and 8). The work was con-

tinued until the War (1915-16), when he largely discontinued his researches. These experiments were the foundation for and a direct approach to the present sound motion picture.

Even though the phonograph and gramophone were considerably improved, there were still many factors that hindered its adoption. One disadvantage that was particularly noticeable during the period before 1910, when there were a great variety of sound devices, was that the longest picture that could be recorded was about two hundred feet, due to limitation of size of record. Most talking pictures were only one hundred feet long.

The maximum playing time of a twelve-inch disk record at that time was five minutes, and for the more universally used ten-inch records, the time was only three or four minutes. The ten-inch record, as used by Cinephone in 1909, accommodated about one hundred and fifty feet of film.

David S. Hulfish, in the *Cyclopedia of Motion Picture Work* published by the American Technical Society, in Chicago, in 1914, says:

"The Graphophone has not been perfected for the minor sounds of nature. The human voice is about the limit for the sound record. Voices and musical instruments are the standard repertoire of the talking machine, other records being the exception rather than the rule. This limitation of the Graphophone limits the combination sight-and-sound entertainment to dramatic and vaudeville incidents, dancing and singing."

Later in the chapter he says:

"In producing a talking picture where several actors are involved, the method of manufacture is to make the talking record first, and then fit a motion picture to it. To do this, the actors are well drilled in their parts, so that they will be able to produce the performance twice, once in sound for the sound record and once in action for the picture record."

#### EXPERIMENTAL WORK OF THEODORE W. CASE

Unaware of the problems of the talking picture, Theodore W. Case began a series of experiments in 1911 that were to be far reaching. On January 22nd, Case wrote to his mother:

"Most of my time is now taken up in experimenting with a selenium cell with the idea in mind of photographing sound-waves and using the positives as records for a new kind of phonograph, or, rather, it would be called a lithograph, I suppose."

On February 12, 1911, he wrote:

"Yesterday I at last succeeded in transmitting sound by light. I used the principle of the manometric flame."

Although Case was interested at that time in the problem of photographing sound, he did not conduct his experiments with the idea of combining motion pictures with sounds. Shortly thereafter his experiments in photographing sound were laid aside, and other things attracted his interest. In 1916, he began researches that were to contribute years later to the development of the talking picture photoelectric cell, in the electrical characteristics of many materials. By 1917 he had filed an application for a patent on a new substance (bismuth-sulfur compound) having variable electrical resistance in relation to the intensity of light striking it. The patent was granted July 8, 1919.<sup>27,28</sup>

The photoelectric cell<sup>29</sup> was the solution of one of the major problems of the sound pioneers. With it they could reproduce the recorded sound-track in sufficient volume. The first Case Photoelectric Cell developed in the Case Research Laboratory at Auburn, N. Y. (1913), was known as the *thalofide* (often spelled *thallafide*) cell.<sup>30,31,32</sup> There were, of course, other contemporary photoelectric cells, but they had little use, and, according to available data, were used to no great extent during this experimental stage of the talking picture.<sup>33</sup>

#### THE DE FOREST PHOTION TUBE

In the meantime Lee de Forest had been working on a sound system. By 1919 he had filed his first patent on a glow-lamp, which he later called the "photion" tube, and which he used in his sound system. It was the forerunner of the tubes that are now used in recording the sound by the "flashing-light" system, which was later developed by Case as the *aeolight*, and introduced as the Fox-Case system. Whereas the Case thalofide cell could reproduce the photographically recorded sound-track, the de Forest photion tube served for recording the original sound record photographically. That meant that successful motion pictures and sound could be recorded side by side upon the same film, and that they could be reproduced.

In the next few years de Forest was granted and assigned thirty-five patents,<sup>34</sup> and by 1923 he had given several successful demonstrations of his *phonofilm*, among which was a demonstration to the press on March 13, 1923, at his New York studio. According to a



# THE RIVOLI

BROADWAY AT 49th STREET NEW YORK CITY

Operated in conjunction with THE RIALTO, Times Square

HUGO RIESENFELD, DIRECTOR

**FIRE NOTICE**—Look around NOW and choose the nearest exit to your seat. In case of fire walk (not run) to THAT EXIT. Do not try to beat your neighbor to the street.

THOMAS J. DRENNAN, Fire Commissioner.

PROGRAM CHANGED EVERY SUNDAY

## PRICES

	EVENINGS		Orchestra 85 cents	{	Admission 77 cents
					War Tax 8 cents
			Balcony 50 cents	{	Admission 45 cents
					War Tax 5 cents
	MATINEES		Orchestra 50 cents	{	Admission 45 cents
					War Tax 5 cents
			Balcony 30 cents	{	Admission 27 cents
					War Tax 3 cents
	LOGES		Always 99 cents	{	Admission 90 cents
					War Tax 9 cents

The Rivoli opens at noon daily, performances begin at 12 noon, 2:15, 4:15, 7:30\* and 9:30 p. m. Sunday first performance starts at 1. Asterisks indicate full presentation with orchestra, soloists and scenic effects. J. Van Cleft Cooper and Frank Stewart Adams at the organ.

## PROGRAM

Week of April 15th, 1923

### RIVOLI ORCHESTRA

FREDERICK STAHLBERG, Conductor WILLIE STAHL, Asst. Conductor

## 1. OVERTURE

### "ORPHEUS IN THE LOWER WORLD"

Jacques Offenbach

FREDERICK STAHLBERG and WILLIE STAHL conducting

Although Orpheus is not mentioned in the Homeric poems, the story of his attempting to bring back his dead wife, Eurydice, from the lower regions was a favorite of the Greeks and has been ever since. It was a subject of the first grand opera ever written, by Peri in 1600, and is the theme of Gluck's most famous opera, produced in 1762. Offenbach's burlesque of the old myth was produced in Paris in 1858, and its jolly tune made it a great success. The overture is one of the finest specimens of light music.

## 2. THE PHONOFILM

*The Phonofilm is the latest invention of Dr. Lee de Forest and is a long stride forward in the development of the talking pictures. For the first time it has been made possible to record the picture and the voice or music on the same film, thus insuring perfect synchronization. This is the first public showing.*

FIG. 9. Section of Rivoli Theater (N. Y.) program for the week of April, 15, 1923, announcing the de Forest phonofilm demonstration.

program of the Rivoli Theater (Fig. 9), New York, for the week of April 15, 1923:

"The Phonofilm is the latest invention of Dr. Lee de Forest and is a long stride forward in the development of the talking pictures. For the first time it has been made possible to record the picture and voice or music on the same film, thus insuring perfect synchronization. This is the first public showing."



From here the popularity of his sound-on-film pictures extended to other theaters and to other cities.<sup>35,36,37,38</sup>

At this stage, however, the quality of the reproduced sound was not of sufficient excellence to interest the public greatly. The sound was so incomplete in harmonics, so limited in range of intensity, and so unmistakably a "canned" product that no illusion was possible. It was only after the Western Electric Company had introduced a high-quality sound-on-disk system that the motion picture producers became really interested in the application of sound to the motion picture.



FIG. 10

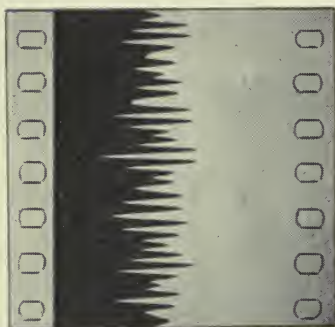


FIG. 11

FIG. 10. (Left) "The Kiss," from an Edison picture of 1895.

FIG. 11. (Right) Sound-track made by system devised by Rühmer  
(*Scientific American*, 1901).

This product of the Western Electric Company was a result of many years of research work in the Bell Telephone Laboratories which made available the condenser transmitter, the distortionless vacuum tube amplifier, and certain adaptations of the telephone receiver and transmitter to fit the graver and pick-up needle. The design of a precision system of synchronization took only a relatively short time of a small group of workers.

#### FIRST COMMERCIALY SUCCESSFUL SOUND PICTURE FEATURES

The talking picture had become a possibility; science had triumphed. It now depended upon a courageous business man with foresight to give the pictures to the public. The man to do it was

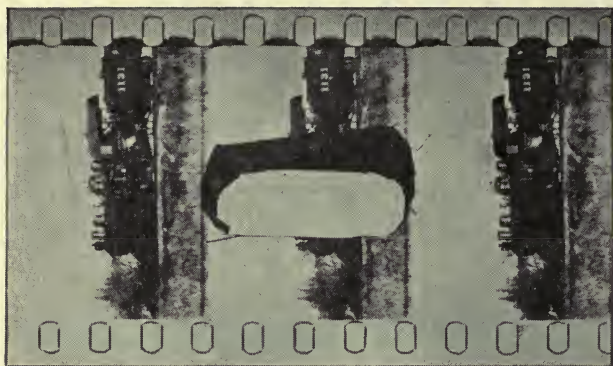


FIG. 12 (c)

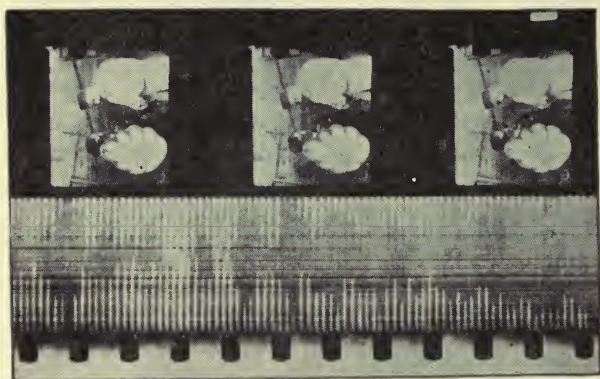


FIG. 12 (b)

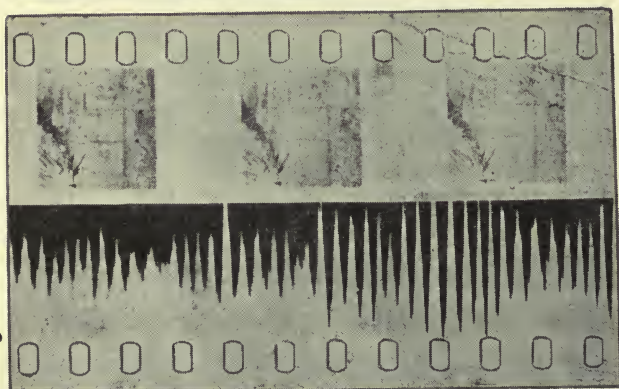


FIG. 12 (a)

(a). Variable-area sound-track and picture made by Lauste in 1910.

(b). Variable-density sound-track made by Lauste in 1911.

(c). Synchronization mark in a film made by E. H. Amet in 1912 for a sound-on-disk system.

Harry Warner. On the night of August 7, 1926, due to his enterprise, Warner Brothers released their first sound picture, *Don Juan*, starring John Barrymore, opening at the New York Warner Brothers Theater on Broadway using a sound system developed by the Western Electric Company and the Bell Telephone Laboratories and commercially known as the "Vitaphone." In this first program Will Hays appeared on the screen in a talking "short," wherein he prophesied that the entire course of screen history was to be altered by the advent of sound. It was revolutionized.

Warner Brothers, however, did not record sound-on-film; instead, in 1925 they had become interested in a disk system developed by the Western Electric Company, who had also a sound-on-film system. Warner Brothers, as well as a number of other studios, had been offered the choice of either a sound-on-film or a disk system developed in the Bell Telephone Laboratories.

Amplification and disk recording had been perfected in the Bell Telephone Laboratories and had been licensed a number of years earlier to the Victor Talking Machine Corporation for use in their phonographs. Practically the same phonographic system was used by Warner Brothers, and by adding loud speakers and amplifiers to this system, it was possible to fill the theater with sound of acceptable quality. A synchronous motor was added to the phonographic system to keep the camera and the sound records in synchronism during the recording.

The second Warner Brothers picture released with sound sequences on January 23, 1927, was the *Jazz Singer*, with Al Jolson, and the first completely synchronized feature picture was *The Lights of New York*, released on July 15, 1928. The cast included Helene Costello, Cullen Landis, Mary Carr, Gladys Brockwell, and others. It carried dialog through its entire length.

In 1930 Warner Brothers discontinued disks for the most part, in favor of sound-on-film, because of the expense of breakage and shipping the 16-inch records. *Vitaphone* was the name coined by the Warner Brothers for their sound pictures.

#### MOVIETONE SOUND SYSTEM

In the meantime, Theodore Case, who had been making thalofide cells for Lee de Forest, had extended his interest in the talking picture to the point of developing his own system. He is said to have started work on a sound camera employing a modulating oxyacetylene flame



as early as 1922. In subsequent experiments he found that a vacuum tube that he had developed for his infrared-ray signal system could be modulated at low voltages for recording sound. This led to the development of the aeolight or "flashing lamp" and to the Fox-Case sound system in which William Fox acquired a substantial interest on September 20, 1926.

The first commercial exhibition made by Fox-Case of Movietone sound, which at this time was the result of combining Western Electric Company and Case features, was a short featuring Raquel Meller, who sang a number of songs. It was released in conjunction with *What Price Glory* on January 21, 1927. The system was again demonstrated in New York on February 25, 1927. On May 29,



FIG. 13

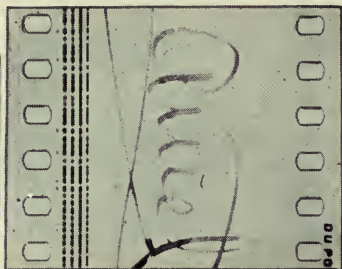


FIG. 14

FIG. 13. Specimen of de Forest phonofilm (1911).  
FIG. 14. Multiple track made by E. H. Amet (1922).

1927, the first complete Movietone program was shown in the Janet Gaynor and Charles Farrell picture, *Seventh Heaven*.<sup>39</sup>

The first outdoor sound picture was the Fox Movietone feature, *In Old Arizona*, starring Warner Baxter, first shown at the Los Angeles Criterion Theater, December 25, 1928. The first issue of Movietone News was released at the Roxy Theater, New York, on April 25, 1928. Although de Forest had made a few news subjects earlier, this was the first talking newsreel.<sup>40</sup> On January 5, 1927, Vitaphone, developed by Western Electric, was cross-licensed with Fox-Case Movietone. Under this arrangement the Western Electric Company manufactured equipment for both systems.

In the meantime, the Bell Telephone Laboratories had developed the light-valve system of recording as contrasted to the flashing lamp system of Fox-Case.





FIG. 15



FIG. 16

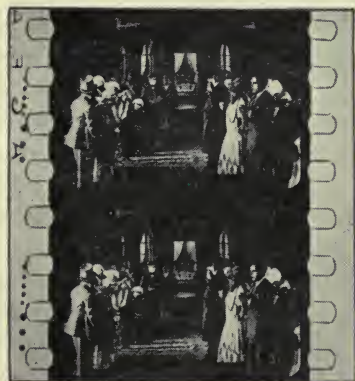


FIG. 17

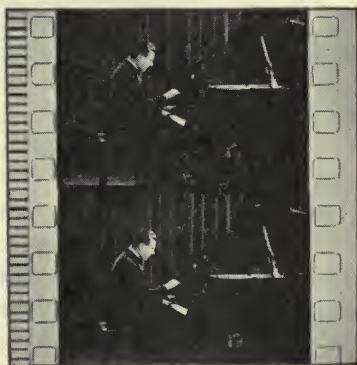


FIG. 18

FIG. 15. Early photophone recording.

FIG. 16. Movietone synchronizing mark.

FIG. 17. Showing a method employed in Germany of producing sound effects (1922). Notes at the bottom of each frame served as a guide for musicians who sat in the orchestra and sang the music. With earlier pictures, the musicians sang behind, or beside, the screen.

FIG. 18. Sound-track along outer edge of the film (from Germany).

In the flashing-lamp system the sound record is made by recording photographically the variations of intensity of a lamp. These variations result from a fluctuating current received through an amplification system from a microphone. On the other hand, in the light-value method a constant source of light is used, and the sound pattern is made by varying the width of a narrow aperture. This aperture is formed by a loop of duralumin ribbon stretched between magnets so that the two strands of the loop are parallel and about 0.001 inch apart. When the modulated current from the microphone passes through the ribbons, the distance between the two strands varies. These variations when photographed result in a sound record of the variable density type.

This development of the Bell Telephone Laboratories was the result of the efforts of a large number of workers, particularly Edward C. Wentz and Donald MacKenzie. Wentz developed the condenser transmitter for the telephone. The condenser microphone was used also in the de Forest system, and has been applied extensively in the recording of sound pictures in recent years. Wentz was awarded the Progress Medal of the Society in 1935 in recognition of his researches. MacKenzie was largely responsible for coördinating the various elements and for working out the necessary conditions for processing variable-density sound records. The contributions of other telephone engineers should not be overlooked. In their many years of practical experience and research into the problems of electrical communication circuits they have contributed much to the talking picture. Included in this group is H. B. Wier, who was among the first to understand the advantages of re-recording and the use of equalization networks. On the commercial side, and in the organization of developments in the Bell Telephone Laboratories, the steady support given by Edward B. Craft, Chief Engineer, was extremely valuable, and perhaps served as the most stimulating force in maintaining the interest of this research organization.\*

By May 15, 1928, Metro-Goldwyn-Mayer, Paramount-Famous Players-Lasky Corporation, and United Artists Studio had identified themselves with Western Electric, using the light-valve system.

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\*This survey in sound pioneering from this point concerns itself largely with the commercial application of the various sound systems rather than detailing the improvements and contributions of the engineers in the laboratories. Their work is of inestimable value to the present high quality of sound engineering and the record of their work remains to be written.

Very shortly thereafter, First National, Christie, and Universal Pictures were also licensed by Western Electric.

Metro-Goldwyn-Mayer produced the first short in color and sound, namely, *Gus Edward's Color-Tone Revue*, first shown at the Carhay Circle Theater, Los Angeles. The first feature having color (two-color Technicolor) as well as sound was the Metro-Goldwyn-Mayer *Broadway Melody*, released on February 17, 1929. It as well as most other pictures of the time, was made in both silent and talkie versions.



FIG. 19. 42-mm. track with the sound outside the perforations (from Germany).

The necessity of making the two versions may be seen from the fact that by September 27, 1928, only six hundred theaters were wired for sound by Western Electric. At that time there were plans to wire another four hundred by January 1st, and an additional 2000 during 1929.

#### THE RCA PHOTOPHONE SYSTEM

Installations of RCA Photophone equipment were begun on October 1, 1928.<sup>41</sup> *Photophone*, a system developed by the Radio Corporation of America, Westinghouse Electric & Manufacturing Co., and General Electric Company, entered the sound-picture situation January 7, 1928, when a substantial interest was acquired in Film Booking Offices (known in Hollywood then as F. B. O. Studios). In March of that year negotiations were begun for the acquisition



of the Victor Talking Machine Corporation, and were consummated on January 6, 1929. The system with improvements was introduced as the Photophone February 1, 1928, and was demonstrated before the Society at Hollywood in April, 1928, by H. B. Marvin.<sup>42</sup> The first Photophone feature was the F. B. O. picture, *The Perfect Crime*, released on June 17, 1928.

Charles A. Hoxie of the General Electric Company, who was responsible for much of the pioneering research in the Photophone system, started working with the sound and photographic problem in

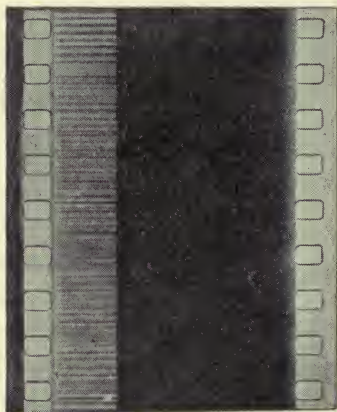


FIG. 20

FIG. 20. Specimen of cinephone recording of 1928, used with Mickey Mouse cartoons.

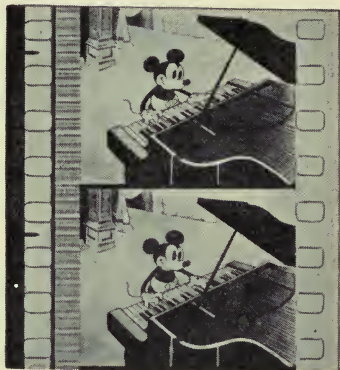


FIG. 21

FIG. 21. Recent Mickey Mouse recording.

1920. The device he constructed at the time was known as the *pallophotophone*. His first camera for recording sound was made in January, 1921, with which he recorded speeches of President Coolidge, the Secretary of War, and others. The speeches were broadcast over radio station WGY in 1922. This led directly to the commercial models of the photophone equipment. A demonstration including the *Volga Boatman* was given before motion picture producers at Schenectady in 1926, and, as a sound and picture device, the *kinegraphone*, as it was termed, was demonstrated at the State Theater in Schenectady, N. Y., in September, 1927. An exhibition including reels of *Flesh and the Devil* was given at the Rivoli Theater in New York early in 1927.

In contrast to the variable-density type of record, the RCA Photophone method of recording sound in the earlier systems was somewhat similar in basic principle to the Lauste method in 1910. A constant source of light was used, which played upon a mirror attached to wire ribbons stretched between electromagnets. When the electromagnets received the electrical impulses from a microphone the mirror was deflected. The movement of the light-beam reflected from the mirror was photographed, producing what is known as a variable-width sound-track.

The system has been improved recently by substituting for the wire ribbons an armature, which turns upon an axis between the poles of an electromagnet, the mirror being attached to the armature. The voice currents from the microphone energize the electromagnet which in turn deflects the armature and mirror. Some of the earliest RCA Photophone recordings were the RKO *Dixiana*, the Pathe-de Mille *King of Kings*, and *The Godless Girl*.

Research work devoted to the problem of extending the frequency range and reducing distortion in both recording and reproducing systems conducted by the research engineers of the RCA Victor Company resulted in the development of a commercial system having an improved signal-to-noise ratio, increased frequency range, and reduced harmonic distortions. The RCA Photophone high-fidelity system was announced in 1932. Corresponding improvements were also made in the Western Electric System.

The improvements in the Photophone system were a result of the efforts of a large number of research workers located at Camden, N. J., after the Photophone interests were absorbed from the General Electric Company by the RCA Corporation. Most noteworthy among these workers were M. C. Batsel, G. L. Dimmick, E. W. Kellogg, and E. W. Engstrom. Kellogg was awarded the Progress Medal of the Society in 1937 in recognition of his researches.

Patents on noise-reduction were also granted to Siemens and Halske.<sup>43</sup> In referring to the experimental work of the German sound engineers, it should be noted that Ernst Vorbeck of Berlin proposed the idea of using electric amplifiers for sound registration on March 26, 1913 (D. R. P. 285,492). On May 4, 1919, Hans Vogt, Jo Engl, and Joseph Massolle filed the first of a series of patents covering sound recording (D. R. P. 417,967). Engl had first become interested in what he called "talking Pictures" in 1912. These three engineers perfected the Tri-Ergon process, which was adopted by "Tobis" and

the first public demonstration was held at the Apollo Theater in Paris in May, 1929, under the direction of Dr. Hans Henkel.<sup>44,45</sup>

Besides the two major systems, developed in the United States, the Western Electric Movietone and the RCA Victor Photophone, there were a large number of systems of lesser importance: notably the *Cinephone* system, developed by Pat Powers, R. I. Halpenny, and William Garity, which was distinguished by being the system used for recording the first sound cartoon, a Mickey Mouse picture

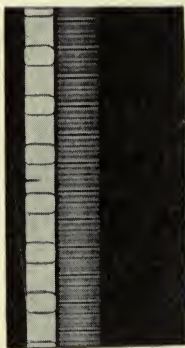


FIG. 22



FIG. 23



FIG. 24

FIG. 22. Split 35-mm. recording used by Metro-Goldwyn-Mayer and Universal as an economy measure. First used by M-G-M in 1931.

FIG. 23. RCA 16-mm. sound-film, announced in spring of 1932.

FIG. 24. High-fidelity RCA recording, announced in May, 1932.

entitled *Steamboat Willie*. This cartoon, which incidentally, was the first of the Mickey Mouse series, was released at the Colony Theater, New York, in September, 1928. The Cinephone was basically the de Forest phonofilm system.

Among other systems that had some use were the Hanaphone, Vocafilm, Biophone, Kolstatone, Milotone, Reeltone, and Phonoscope. There were more than eighty film and disk systems put out by different companies; most of them being based upon the Western Electric or RCA Photophone principles. For recording there were ten disk and five sound-film systems available.<sup>46, 47, 48, 49</sup>



This number of systems brought forth the question of standardization and interchangeability. On July 7, 1928, this question first arose when Western Electric Company gave permission to RCA Photophone to show *King of Kings* on Western Electric equipment at the Rivoli Theater, New York. Photophone had been using a wider sound-track (100 mils) than was usual with the variable-density type of record, until July 17, 1928, at which time they adopted the 80-mil width as used with the latter. This made it possible to reproduce photophone recordings in the comparatively large number of theaters equipped with Western Electric apparatus. Theater installations of RCA Photophone equipment began in October, 1928.

The question of interchangeability was largely settled on December 30, 1928, when J. E. Otterson, then President of Electrical Research Products, Inc., a subsidiary of the Western Electric Company, announced that an agreement had been reached among licensees of the various systems.

Fox Studios was one of the first companies to discontinue making dual versions. Beginning March 1, 1929, silent versions were discontinued and only talking pictures were made thereafter. This decision was somewhat daring, since a large number of the leaders of the industry still felt that sound-films were only a passing fad. In 1929, 348 talking and 400 silent pictures were made. Metro-Goldwyn-Mayer in November of that year began making foreign versions. Europe, in the meantime, was following a more conservative plan in making talking pictures.

The sound-film had become established, and with it came a new industry. The silent motion picture with its dramatic devices were in the discard, and in its place was an entirely new screen medium. In the scramble of 1928-29, a new dramatic form was evolved. The entire motion picture had changed.<sup>50,51,52,53</sup>

Reproductions of specimens of film showing the various forms of sound-track evolved in the development of the talking picture are shown in Figs. 10-24, enlarged somewhat in order to show the sound-tracks clearly. The original specimens are in the SMPE motion picture exhibit at the Los Angeles Museum.

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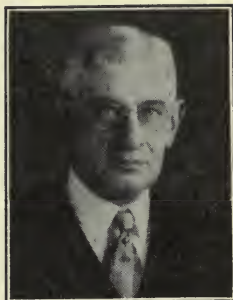
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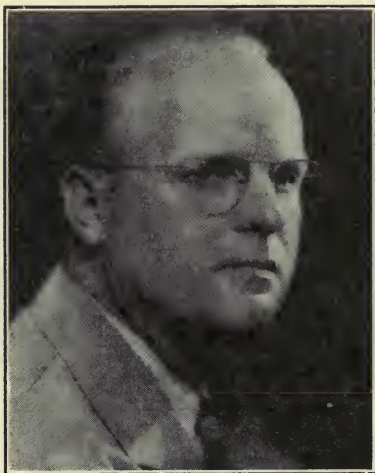
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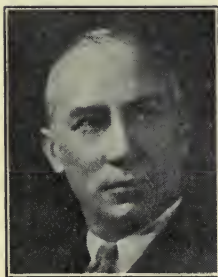
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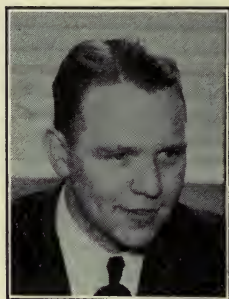
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J. FRANK, JR.		S. HARRIS

##### *Hotel and Transportation*

F. E. ALTMAN, *Chairman*

A. A. COOK	C. E. IVES	E. C. ROLAND
E. C. FRITTS	L. R. MARTIN	W. WESTWATER

##### *Publicity Committee*

J. HABER, *Chairman*

G. A. CHAMBERS	W. R. GREENE	G. E. MATTHEWS
H. A. GILBERT	F. C. ELLIS	S. HARRIS



**Banquet and Dance**I. L. NIXON, *Chairman*

E. K. CARVER  
WALTER CLARK  
R. M. EVANS

N. B. GREEN  
G. A. BLAIR  
J. I. CRABTREE

R. KINGSLAKE  
O. SANDVIK  
H. B. TUTTLE

**Ladies' Reception Committee**MRS. C. M. TUTTLE, *Hostess*

MRS. A. A. COOK  
MRS. R. M. CORBIN  
MRS. R. M. EVANS

MRS. W. H. INGRAM  
MRS. L. A. JONES  
MRS. L. R. MARTIN  
MRS. G. E. MATTHEWS

MRS. I. L. NIXON  
MRS. W. B. RAYTON  
MRS. H. B. TUTTLE

**Projection**H. F. HEIDEGGER, *Chairman*

W. E. BELCER  
B. BLACKFORD  
R. J. DWYER  
R. J. FISHER

G. W. HOWITT  
W. H. INGRAM  
F. BOEKHOUT  
C. MASON

W. H. REPP  
E. F. TETZLAFF  
L. M. TOWNSEND  
C. M. WEBER

Officers and Members Rochester Projectionists Local No. 253

**HEADQUARTERS**

The headquarters of the Convention will be the Sagamore Hotel, where excellent accommodations and moderate rates are assured. A reception parlor will be provided as headquarters for the Ladies' Committee.

Hotel reservation cards mailed to the members of the Society several weeks ago should be filled out and mailed immediately to the Sagamore Hotel so that suitable accommodations may be reserved, subject to cancellation if unable to attend the Convention.

The following European-plan day rates are extended by the Sagamore Hotel to Society members and guests attending the Convention (all rooms are outside rooms with bath):

Room for one person	\$3.00 to \$5.00
Room for two persons, double bed	4.50 to 6.00
Room for two persons, twin beds	6.00 to 7.00
Suite accommodations, one to four persons	12.00 and up

The following hotel garage rates will be available to SMPE delegates and guests who motor to the Convention: 24-hr. inside parking, 75¢; outside parking (daily), 25¢.

The colorful *Sagamore Room* on the main floor of the Hotel offers special breakfast, luncheon, and dinner menus at moderate prices.

Golfing privileges at several Rochester country clubs may be arranged for either by the hotel management or at the SMPE registration headquarters.

## REGISTRATION

Convention registration and information headquarters will be located on the Sagamore Hotel roof, adjacent to the *Glass House*, where technical sessions and symposiums will be held.

Members and guests attending the Convention will be expected to register, and so help to defray the Convention expenses. Convention badges and identification cards will be provided for admittance to all regular and special sessions during the Convention. The identification card will also be honored through the courtesy of Loew's Theaters, Inc., at Loew's *Rochester* Theater and, through the courtesy of Monroe Amusements, Inc., at the *Palace*, *Regent*, and *Century* Theaters.

## TECHNICAL SESSIONS

All the technical sessions of the Convention will be held in the *Glass House* on the roof of the Sagamore Hotel with the exception of Wednesday morning and evening, as described below. Members should note that the banquet, which at past conventions has always been held on Wednesday evening, this time has been scheduled for Tuesday evening to permit holding a special meeting on Wednesday evening at the *Eastman* Theater.

Wednesday, May 7th, will be devoted to a joint meeting of the Acoustical Society of America and the SMPE, consisting of a symposium of papers by engineers of the Bell Telephone Laboratories in the morning and afternoon. In the evening a demonstration of stereophonic sound will be given by the Bell Telephone Laboratories at the *Eastman* Theater.

## LUNCHEON AND BANQUET

The usual Informal Get-Together Luncheon for members, their families, and guests will be held in the *Starlight Room* on the hotel roof on Monday, May 5th, at 12:30 P. M. Luncheon and banquet tickets should be procured when registering.

The 48th Semi-Annual Banquet and Dance will be held in the *Starlight Room* on the hotel roof on Tuesday evening, May 6th, at 7:30 P. M.: music and entertainment. Banquet tickets should be procured and tables reserved at registration headquarters by noon of Tuesday, May 6th.

## LADIES' PROGRAM

Mrs. C. M. Tuttle, *Convention Hostess*, and members of her Committee are arranging a very attractive program of entertainment for the ladies attending the Convention. A reception parlor will be provided for the use of the Committee during the Convention.

## PROGRAM

**Monday, May 5th**

- 9:00 a. m.      *Sagamore Hotel Roof*  
Registration
- 9:30 a. m.-12:00   *Glass House, Hotel Roof*  
Technical session
- 12:30 p. m.      *Starlight Room, Hotel Roof*  
Get-Together Luncheon for members, their families, and guests. Brief addresses by several prominent speakers
- 2:00 p. m.      *Glass House, Hotel Roof*  
Technical session
- 8:00 p. m.      *Glass House, Hotel Roof*  
Technical session

**Tuesday, May 6th**

- 9:00 a. m.      *Sagamore Hotel Roof*  
Registration
- 9:30 a. m.      *Glass House, Hotel Roof*  
Society Business  
Technical session
- 12:30 p. m.      Luncheon period  
Open afternoon
- 7:30 p. m.      *Starlight Room, Hotel Roof*  
Semi-Annual Banquet and Dance of the SMPE: addresses and entertainment: music, dancing, and entertainment

**Wednesday, May 7th**

*Joint Meeting of the Acoustical Society of America and the Society of  
Motion Picture Engineers*

- 10:00 a. m.      *Eastman Theater*  
Stereophonic sound papers session
- 12:30 p. m.      Luncheon period
- 2:00 p. m.      *Glass House, Hotel Roof*  
Stereophonic sound papers session
- 8:00 p. m.      *Eastman Theater*  
Stereophonic sound demonstration for the SMPE Convention and invited groups. Admission only by SMPE identification card, or special invitation card

**Thursday, May 8th**

- 10:00 a. m.      *Glass House, Hotel Roof*  
Technical session
- 12:30 p. m.      Luncheon period
- 2:00 p. m.      *Glass House, Hotel Roof*  
Technical session

## ADJOURNMENT

W. C. KUNZMANN,  
*Convention Vice-President*



## SOCIETY ANNOUNCEMENTS

### ERRATUM

#### REPORT OF THE SMPE STANDARDS COMMITTEE

(*March, 1941, page 264*)

In the "Report of the SMPE Standards Committee," published in the March, 1941, issue of the JOURNAL, p. 264, the chart showing the specifications for raw-stock cores for 35-mm film was headed "American Standards."

This was in error, as the chart should have been headed "SMPE Recommended Practices."

The specifications have not yet been submitted to the Sectional Committee on Motion Pictures (Z-22) of the American Standards Association, and hence should not be regarded as "American Standards."

### 1941 SPRING CONVENTION

SAGAMORE HOTEL, ROCHESTER, N. Y.

MAY 5th-8th, INC.

Plans for the approaching Rochester Convention are proceeding rapidly and the tentative program of presentations will be mailed to the members of the Society in the near future.

Preliminary bulletins and hotel reservation cards have recently been mailed to the membership, and all members planning to attend the Convention should be sure to return their reservations cards without delay. The Acoustical Society of America will meet in Rochester May 5th and 6th, concurrently with the first two days of the SMPE Convention, and promptness in making reservations may be necessary in order to secure satisfactory accommodations.

Further details concerning the Convention will be found on page 455 of this issue of the JOURNAL.

### ATLANTIC COAST SECTION

At a meeting held at the Hotel Pennsylvania, New York, N. Y., on the evening of March 19th, Dr. Harry F. Olsen of the RCA Manufacturing Company, Camden, N. J., presented a comprehensive talk on the subject of "Microphones for Motion Pictures—Their Uses, Characteristics and Pick-Up Technics."

The meeting was unusually well attended and considerable discussion followed the presentation. Preceding the meeting, a group of members met for supper in the Coffee Shop of the Hotel.

### MID-WEST SECTION

On February 25th, the regular monthly meeting of the Section was held in the meeting rooms of the Western Society of Engineers, Chicago, Ill.

The subject of the meeting, *The Alchemist in Hollywood*, was a 16-mm sound-film showing, in an educational and technical way, the nature of motion picture activities in Hollywood. The main subject was prefaced by a short talk by the Chairman of the Section.

## PACIFIC COAST SECTION

The February meeting of the Section was held at the Samuel Goldwyn Studios in Hollywood on February 25th. Mr. Roy S. Leonard presented a 16-mm Kodachrome picture produced for the Lighting Department of Seattle, Wash., entitled *The Million Horsepower Skagit*. The picture presented the story of the scenic beauty and the power development of the 1200 square-mile mountain area of the Skagit River watershed.

In addition, Mr. Carl Dunning presented a paper on *Making 16-Mm Kodachrome Duplicates*, as done in the Dunningcolor Laboratories. The paper was accompanied by a demonstration reel.

Also, a paper prepared by Mr. L. R. Martin of the Eastman Kodak Company, on the subject of *The Motion Picture as a Tool in Science and Engineering* was presented, accompanied by demonstration films.

CONSTITUTION AND BY-LAWS  
OF THE  
SOCIETY OF MOTION PICTURE ENGINEERS\*

CONSTITUTION

*Article I*

*Name*

The name of this association shall be SOCIETY OF MOTION PICTURE ENGINEERS.

*Article II*

*Object*

Its objects shall be: Advancement in the theory and practice of motion picture engineering and the allied arts and sciences, the standardization of the equipment, mechanisms, and practices employed therein, the maintenance of a high professional standing among its members, and the dissemination of scientific knowledge by publication.

*Article III*

*Eligibility*

Any person of good character may be a member in any class for which he is eligible.

*Article IV*

*Officers*

The officers of the Society shall be a President, a Past-President, an Executive Vice-President, an Engineering Vice-President, an Editorial Vice-President, a Financial Vice-President, a Convention Vice-President, a Secretary, and a Treasurer.

The term of office of the President, the Past-President, the Executive Vice-President, the Engineering Vice-President, the Editorial Vice-President, the Financial Vice-President, and the Convention Vice-President shall be two years, and the Secretary and the Treasurer one year. Of the Engineering, Editorial, Financial, and Convention Vice-Presidents, two shall be elected alternately each year, or until their successors are chosen. The President shall not be immediately eligible to succeed himself in office.

*Article V*

*Board of Governors*

The Board of Governors shall consist of the President, the Past-President, the five Vice-Presidents, the Secretary, the Treasurer, the Section Chairmen, and

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\* Corrected to March 15, 1941.

five elected Governors. Two, and three, of the Governors shall be elected alternately each year to serve for two years.

### **Article VI**

#### *Meetings*

There shall be an annual meeting, and such other meetings as stated in the By-Laws.

### **Article VII**

#### *Amendments*

This Constitution may be amended as follows: Amendments shall be approved by the Board of Governors, and shall be submitted for discussion at any regular members' meeting. The proposed amendment and complete discussion then shall be submitted to the entire Active, Fellow, and Honorary membership, together with letter ballot as soon as possible after the meeting. Two-thirds of the vote cast within sixty days after mailing shall be required to carry the amendment.

### **BY-LAWS**

#### *By-Law I*

#### *Membership*

*Sec. 1.*—The membership of the Society shall consist of Honorary members, Fellows, Active members, Associate members, and Sustaining members.

An **Honorary member** is one who has performed eminent services in the advancement of motion picture engineering or in the allied arts. An Honorary member shall be entitled to vote and to hold any office in the Society.

A **Fellow** is one who shall not be less than thirty years of age and who shall comply with the requirements of either (a) or (b) for Active members and, in addition, shall by his proficiency and contributions have attained to an outstanding rank among engineers or executives of the motion picture industry. A Fellow shall be entitled to vote and to hold any office in the Society.

An **Active member** is one who shall be not less than 25 years of age, and shall be:

(a) A motion picture engineer by profession. He shall have been engaged in the practice of his profession for a period of at least three years, and shall have taken responsibility for the design, installation, or operation of systems or apparatus pertaining to the motion picture industry.

(b) A person regularly employed in motion picture or closely allied work, who by his inventions or proficiency in motion picture science or as an executive of a motion picture enterprise of large scope, has attained to a recognized standing in the motion picture industry. In case of such an executive, the applicant must be qualified to take full charge of the broader features of motion picture engineering involved in the work under his direction.

(c) An Active member is privileged to vote and to hold any office in the Society.

An **Associate member** is one who shall be not less than 18 years of age, and shall be a person who is interested in or connected with the study of motion picture



technical problems or the application of them. An Associate member is not privileged to vote, to hold office or to act as chairman of any committee, although he may serve upon any committee to which he may be appointed; and, when so appointed, shall be entitled to the full voting privileges of a committee member.

A **Sustaining member** is an individual, a firm, or corporation contributing substantially to the financial support of the Society.

*Sec. 2.*—All applications for membership or transfer, except for honorary or fellow membership, shall be made on blank forms provided for the purpose, and shall give a complete record of the applicant's education and experience. Honorary and Fellow membership may not be applied for.

*Sec. 3.*—(a) An **Honorary** membership may be granted upon recommendation of the Board of Governors when confirmed by a four-fifths majority vote of the Honorary members, Fellows, and Active members present at any regular meeting of the Society. An Honorary member shall be exempt from all dues.

(b) Fellow membership may be granted upon recommendation of at least three-fourths of the Board of Governors.

(c) Applicants for Active Membership shall give as reference at least three members of Active or of higher grade in good standing. Applicants shall be elected to membership by the unanimous approval of the entire membership of the appropriate Admissions Committee. In the event of a single dissenting vote or failure of any member of the Admissions Committee to vote, the application shall be referred to the Board of Governors, in which case approval of at least three-fourths of the Board of Governors shall be required.

(d) Applicants for Associate membership shall give as reference at least one member of higher grade in good standing. Applicants shall be elected to membership by approval of a majority of the appropriate Admissions Committee.

## ***By-Law II***

### *Officers*

*Sec. 1.*—An officer or governor shall be an Honorary, a Fellow, or Active member.

*Sec. 2.*—Vacancies in the Board of Governors shall be filled by the Board of Governors until the annual meeting of the Society.

## ***By-Law III***

### *Board of Governors*

*Sec. 1.*—The Board of Governors shall transact the business of the Society between members' meetings, and shall meet at the call of the president.

*Sec. 2.*—A majority of the Board of Governors shall constitute a quorum at regular meetings.

*Sec. 3.*—When voting by letter ballot, a majority affirmative vote of the total membership of the Board of Governors shall carry approval, except as otherwise provided.

*Sec. 4.*—The Board of Governors, when making nominations to office, and to the Board, shall endeavor to nominate persons, who in the aggregate are representative of the various branches or organizations of the motion picture industry,

to the end that there shall be no substantial predominance upon the Board, as the result of its own action, of representatives of any one or more branches or organizations of the industry.

### *By-Law IV*

#### *Committees*

*Sec. 1.*—All committees, except as otherwise specified, shall be appointed by the President.

*Sec. 2.*—All committees shall be appointed to act for the term served by the officer who shall appoint the committees, unless their appointment is sooner terminated by the appointing officer.

*Sec. 3.*—Chairman of the committees shall not be eligible to serve in such capacity for more than two consecutive terms.

*Sec. 4.*—Standing committees of the Society shall be as follows to be appointed as designated:—

- (a) *Appointed by the President and confirmed by the Board of Governors*
  - Progress Award Committee
  - Honorary Membership Committee
  - Journal Award Committee
  - Admissions Committees
    - (Atlantic and Mid-West Sections)
    - (Pacific Coast Section)
  - European Advisory Committee
- (b) *Appointed by the Engineering Vice-President*
  - Sound Committee
  - Standards Committee
  - Studio Lighting Committee
  - Color Committee
  - Theater Engineering Committee
  - Exchange Practice Committee
  - Non-Theatrical Equipment Committee
  - Television Committee
  - Laboratory Practice Committee
- (c) *Appointed by Editorial Vice-President*
  - Board of Editors
  - Papers Committee
  - Progress Committee
  - Historical Committee
  - Museum Committee
- (d) *Appointed by Convention Vice-President*
  - Publicity Committee
  - Convention Arrangements Committee
  - Apparatus Exhibit Committee
- (e) *Appointed by Financial Vice-President*
  - Membership and Subscription Committee

*Sec. 5.*—Two Admissions Committees, one for the Atlantic and Mid-West Sections, and one for the Pacific Coast Section, shall be appointed. The former

committee shall consist of a chairman and six Fellow or Active members of the Society of which four shall be members of the Board of Governors. The latter committee shall consist of a Chairman and four Fellow or Active members of the Society including all officers or members of the Board of Governors of the Society residing in the Pacific Coast Section.

### ***By-Law V***

#### *Meetings*

*Sec. 1.*—The location of each meeting of the Society shall be determined by the Board of Governors.

*Sec. 2.*—Only Honorary members, Fellows, and Active members shall be entitled to vote.

*Sec. 3.*—A quorum of the Society shall consist in number of one-tenth of the total number of Honorary members, Fellows, and Active members as listed in the Society's records at the close of the last fiscal year.

*Sec. 4.*—The fall convention shall be the annual meeting.

*Sec. 5.*—Special meetings may be called by the president and upon the request of any three members of the Board of Governors not including the president.

*Sec. 6.*—All members of the Society in any grade shall have the privilege of discussing technical material presented before the Society or its Sections.

### ***By-Law VI***

#### *Duties of Officers*

*Sec. 1.*—The **president** shall preside at all business meetings of the Society and shall perform the duties pertaining to that office. As such he shall be the chief executive of the Society, to whom all other officers shall report.

*Sec. 2.*—In the absence of the president, the officer next in order as listed in Article 4 of the Constitution shall preside at meetings and perform the duties of the president.

*Sec. 3.*—The five vice-presidents shall perform the duties separately enumerated below for each office, or as defined by the president:

(a) The **executive vice-president** shall represent the president in such geographical areas of the United States as shall be determined by the Board of Governors, and shall be responsible for the supervision of the general affairs of the Society in such areas, as directed by the president of the Society.

(b) The **engineering vice-president** shall appoint all technical committees. He shall be responsible for the general initiation, supervision, and coordination of the work in and among these committees. He may act as chairman of any committee or otherwise be a member ex-officio.

(c) The **editorial vice-president** shall be responsible for the publication of the Society's JOURNAL and all other technical publications. He shall pass upon the suitability of the material for publication, and shall cause material suitable for publication to be solicited as may be needed. He shall appoint a papers committee and an editorial committee. He may act as chairman of any committee or otherwise be a member ex-officio.

(d) The **financial vice-president** shall be responsible for the financial operations of the Society, and shall conduct them in accordance with budgets approved by



the Board of Governors. He shall study the costs of operation and the income possibilities to the end that the greatest service may be rendered to the members of the Society within the available funds. He shall submit proposed budgets to the Board. He shall appoint at his discretion a ways and means committee, a membership committee, a commercial advertising committee, and such other committees within the scope of his work as may be needed. He may act as chairman of any of these committees or otherwise be a member ex-officio.

(e) The **convention vice-president** shall be responsible for the national conventions of the society. He shall appoint a convention arrangements committee, an apparatus exhibit committee, and a publicity committee. He may act as chairman of any committee, or otherwise be a member ex-officio.

*Sec. 4.*—The **secretary** shall keep a record of all meetings; he shall conduct the correspondence relating to his office, and shall have the care and custody of records, and the seal of the Society.

*Sec. 5.*—The **treasurer** shall have charge of the funds of the Society and disburse them as and when authorized by the financial vice-president. He shall make an annual report, duly audited, to the Society, and a report at such other times as may be requested. He shall be bonded in an amount to be determined by the Board of Governors and his bond filed with the Secretary.

*Sec. 6.*—Each officer of the Society, upon the expiration of his term of office, shall transmit to his successor a memorandum outlining the duties and policies of his office.

### *By-Law VII*

#### *Elections*

*Sec. 1.*—(a) All officers and five governors shall be elected to their respective offices by a majority of ballots cast by the Active, Fellow, and Honorary members in the following manner:

Not less than three months prior to the annual fall convention, the Board of Governors shall nominate for each vacancy several suitable candidates. Nominations shall first be presented by a Nominating Committee appointed by the President, consisting of nine members, including a chairman. The committee shall be made up of two Past-Presidents, three members of the Board of Governors not up for election, and four other Active, Fellow, or Honorary members, not currently officers or Governors of the Society. Nominations shall be made by three-quarters affirmative vote of the total Nominating Committee. Such nominations shall be final unless any nominee is rejected by a three-quarters vote of the Board of Governors present and voting.

The secretary shall then notify these candidates of their nomination in the order of nomination and request their consent to run for office. From the list of acceptances, not more than two names for each vacancy shall be selected by the Board of Governors and placed on a letter ballot. A blank space shall be provided on this letter ballot under each office, in which space the names of any Active, Fellow, or Honorary members other than those suggested by the Board of Governors may be voted for. The balloting shall then take place.

The ballot shall be enclosed in a blank envelope which is enclosed in an outer envelope bearing the secretary's address and a space for the member's name and address. One of these shall be mailed to each Active, Fellow, and Honorary



member of the Society, *not less than forty days in advance of the annual fall convention.*

The voter shall then indicate on the ballot one choice for each office, seal the ballot in the blank envelope, place this in the envelope addressed to the secretary, sign his name and address on the letter, and mail it in accordance with the instructions printed on the ballot. No marks of any kind except those above prescribed shall be placed upon the ballots or envelopes.

The sealed envelope shall be delivered by the secretary to a committee of tellers appointed by the president at the annual fall convention. This committee shall then examine the return envelopes, open and count the ballots, and announce the results of the election.

The newly elected officers and governors of the general Society shall take office on the January 1st following their election.

(b) The first group of vice-presidents, *viz.*, the executive vice-president, engineering vice-president, editorial vice-president, financial vice-president, convention vice-president, and a fifth governor, shall be nominated by the Board of Governors at its first meeting after the ratification of the corresponding provisions of the Constitution; and the membership shall vote on the candidates in accordance with the procedure prescribed in these By-Laws for regular elections of officers so far as these may be applicable.

### ***By-Law VIII***

#### ***Dues and Indebtedness***

*Sec. 1.*—The annual dues shall be fifteen dollars (\$15) for Fellows and Active members and seven dollars and fifty cents (\$7.50) for Associate members, payable on or before January 1st of each year. Current or first year's dues for new members, dating from the notification of acceptance in the Society, shall be prorated on a monthly basis. Five dollars of these dues shall apply for annual subscription to the JOURNAL. No admission fee will be required for any grade of membership.

*Sec. 2.*—(a) Transfer a membership may be made effective at any time by payment of the pro rata dues for the current year.

(b) No credit shall be given for annual dues in a membership transfer from a higher to a lower grade, and such transfers shall take place on January 1st of each year.

(c) The Board of Governors upon their own initiative and without a transfer application may elect, by the approval of at least three-fourths of the Board, any Associate or Active member for transfer to any higher grade of membership.

*Sec. 3.*—Annual dues shall be paid in advance. All Honorary members, Fellows, and Active members in good standing, as defined in Section 5, may vote or otherwise participate in the meetings.

*Sec. 4.*—Members shall be considered delinquent whose annual dues for the year remain unpaid on February 1st. The first notice of delinquency shall be mailed February 1st. The second notice of delinquency shall be mailed, if necessary, on March 1st, and shall include a statement that the member's name will be removed from the mailing list for the JOURNAL and other publications of the Society before the mailing of the April issue of the JOURNAL. Members who are

in arrears of dues on June 1st, after two notices of such delinquency have been mailed to their last address of record, shall be notified their names have been removed from the mailing list and shall be warned unless remittance is received on or before August 1st, their names shall be submitted to the Board of Governors for action at the next meeting. Back issues of the JOURNAL shall be sent, if available, to members whose dues have been paid prior to August 1st.

*Sec. 5.—(a)* Members whose dues remain unpaid on October 1st may be dropped from the rolls of the Society by majority vote and action of the Board or the Board may take such action as it sees fit.

*(b)* Anyone who has been dropped from the rolls of the Society for non-payment of dues shall, in the event of his application for reinstatement, be considered as a new member.

*(c)* Any member may be suspended or expelled for cause by a majority vote of the entire Board of Governors; provided he shall be given notice and a copy in writing of the charges preferred against him, and shall be afforded opportunity to be heard ten days prior to such action.

*Sec. 6.*—The provisions of Sections 1 to 4, inclusive, of this By-Law VIII given above may be modified or rescinded by action of the Board of Governors.

### ***By-Law IX***

#### ***Emblem***

*Sec. 1.*—The emblem of the Society shall be a facsimile of a four-hole film-reel with the letter S in the upper center opening, and the letters M, P, and E, in the three lower openings, respectively. In the printed emblem, the four-hole openings shall be orange, and the letters black, the remainder of the insignia being black and white. The Society's emblem may be worn by members only.

### ***By-Law X***

#### ***Publications***

*Sec. 1.*—Papers read at meetings or submitted at other times, and all material of general interest shall be submitted to the editorial board, and those deemed worthy of permanent record shall be printed in the JOURNAL. A copy of each issue shall be mailed to each member in good standing to his last address of record. Extra copies of the JOURNAL shall be printed for general distribution and may be obtained from the General Office on payment of a fee fixed by the Board of Governors.

### ***By-Law XI***

#### ***Local Sections***

*Sec. 1.*—Sections of the Society may be authorized in any state or locality where the Active, Fellow, and Honorary membership exceeds 20. The geographic boundaries of each Section shall be determined by the Board of Governors.

Upon written petition, signed by 20 or more Active members, Fellows and Honorary members, for the authorization of a Section of the Society, the Board of Governors may grant such authorization.

### *Membership*

*Sec. 2.*—All members of the Society of Motion Picture Engineers in good standing residing in that portion of any country set apart by the Board of Governors tributary to any local Section shall be eligible for membership in that Section, and when so enrolled they shall be entitled to all privileges that such local Section may, under the General Society's Constitution and By-Laws, provide.

Any member of the Society in good standing shall be eligible for non-resident affiliated membership of any Section under conditions and obligations prescribed for the Section. An affiliated member shall receive all notices and publications of the Section but he shall not be entitled to vote at Sectional Meetings.

*Sec. 3.*—Should the enrolled Active, Fellow, and Honorary membership of a Section fall below 20, or should the technical quality of the presented papers fall below an acceptable level, or the average attendance at meetings not warrant the expense of maintaining the organization, the Board of Governors may cancel its authorization.

### *Officers*

*Sec. 4.*—The officers of each section shall be a chairman, and a secretary-treasurer. The Section chairmen shall automatically become members of the Board of Governors of the General Society, and continue in that position for the duration of their terms as chairmen of the local sections. Each Section officer shall hold office for one year, or until his successor is chosen.

### *Board of Managers*

*Sec. 5.*—The Board of Managers shall consist of the Section chairman, the Section past-chairman, the Section secretary-treasurer, and six Active, Fellow, or Honorary members. Each manager of a Section shall hold office for two years, or until his successor is chosen.

### *Elections*

*Sec. 6.*—The officers and managers of a Section shall be Active, Fellow, or Honorary members of the General Society.

Not less than three months prior to the annual Fall Convention of the Society, nominations shall be presented to the Board of Managers of the Section by a Nominating Committee appointed by the chairman of the Section, consisting of seven members, including a chairman. The Committee shall be composed of the present chairman, the past-chairman, two other members of the Board of Managers not up for election, and three other Active, Fellow, or Honorary members of the Section not currently officers or managers of the Section. Nominations shall be made by a three-quarters affirmative vote of the total Nominating Committee. Such nominations shall be final, unless any nominee is rejected by a three-quarters vote of the Board of Managers, and in the event of such rejection the Board of Managers will make its own nomination.

The remainder of the procedure shall be in accordance with the procedure specified for the election of officers of the General Society as described in By-Law VII, Sec. 1A, the word *manager* being substituted for the word *governor*.



*Business*

*Sec. 7.*—The business of a Section shall be conducted by the Board of Managers.

*Expenses*

*Sec. 8.*—(a) As early as possible in the fiscal year, the secretary of each Section shall submit to the Board of Governors of the Society a budget of expenses for the year.

(b) The treasurer of the General Society may deposit with each Section secretary-treasurer a sum of money, the amount to be fixed by the Board of Governors, for current expenses.

(c) The secretary-treasurer of each Section shall send to the treasurer of the General Society, quarterly or on demand, an itemized account of all expenditures incurred during the preceding interval.

(d) Expenses other than those enumerated in the budget, as approved by the Board of Governors of the General Society, shall not be payable from the general funds of the Society without express permission from the Board of Governors.

(e) A Section Board of Managers shall defray all expenses of the Section not provided for by the Board of Governors, from funds raised locally by donation, or fixed annual dues, or by both.

(f) The secretary of the Society shall, unless otherwise arranged, supply to each Section all stationery and printing necessary for the conduct of its business.

*Meetings*

*Sec. 9.*—The regular meetings of a Section shall be held in such places and at such hours as the Board of Managers may designate.

The secretary-treasurer of each Section shall forward to the secretary of the General Society, not later than five days after a meeting of a Section, a statement of the attendance and of the business transacted.

*Papers*

*Sec. 10.*—Papers shall be approved by the Section's papers committee previously to their being presented before a Section. Manuscripts of papers presented before a Section, together with a report of the discussions and the proceedings of the Section meetings, shall be forwarded promptly by the Section secretary-treasurer to the secretary of the General Society. Such material may, at the discretion of the Board of Editors of the General Society, be printed in the Society's publications.

*Constitution and By-Laws*

*Sec. 11.*—Sections shall abide by the Constitution and By-Laws of the Society and conform to the regulations of the Board of Governors. The conduct of Sections shall always be in conformity with the general policy of the Society as fixed by the Board of Governors.



***By-Law XII******Amendments***

*Sec. 1.*—These By-Laws may be amended at any regular meeting of the Society by the affirmative vote of two-thirds of the members present at a meeting who are eligible to vote thereon, a quorum being present, either on the recommendation of the Board of Governors or by a recommendation to the Board of Governors signed by any ten members of active or higher grade, provided that the proposed amendment or amendments shall have been published in the JOURNAL of the Society, in the issue next preceding the date of the stated business meeting of the Society at which the amendment or amendments are to be acted upon.

*Sec. 2.*—In the event that no quorum of the voting members is present at the time of the meeting referred to in Section 1, the amendment or amendments shall be referred for action to the Board of Governors. The proposed amendment or amendments then become a part of the By-Laws upon receiving the affirmative vote of three-quarters of the Board of Governors.

## BACK NUMBERS OF THE TRANSACTIONS AND JOURNALS

Prior to January, 1930, the *Transactions* of the Society were published quarterly. A limited number of these *Transactions* are still available and will be sold at the prices listed below. Those who wish to avail themselves of the opportunity of acquiring these back numbers should do so quickly, as the supply will soon be exhausted, especially of the earlier numbers. It will be impossible to secure them later on as they will not be reprinted.

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The following are available from the General Office of the Society, at the prices noted. Orders should be accompanied by remittances.

*Aims and Accomplishments.*—An index of the *Transactions* from October, 1916, to December, 1929, containing summaries of all articles, and author and classified indexes. One dollar each.

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*Motion Picture Standards.*—Reprints of the *American Standards and Recommended Practice* as published in the March, 1941, issue of the JOURNAL; 50 cents each.

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*Test-Films.*—See advertisement in this issue of the JOURNAL.

# JOURNAL

## OF THE SOCIETY OF

# MOTION PICTURE ENGINEERS

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Volume XXXVI

May, 1941

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# JOURNAL

## OF THE SOCIETY OF

### MOTION PICTURE ENGINEERS

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## REDUCTION OF DEVELOPMENT SPROCKET-HOLE MODULATION\*

M. LESHING, T. INGMAN, AND K. PIER \*\*

**Summary.**—One of the contributing factors to sound-track degradation is sprocket-hole modulation. This is more commonly known as 96-cycle modulation, and results from non-uniform action of developer around the perforations during the time of processing. Its chief remedy is turbulation.

The practical aspects of controlling the amount of sprocket-hole modulation is described herein. Curves showing the increase of this distortion due to diminished turbulation are included as well as those showing the intermodulation of recorded sound by sprocket-hole agitation. The turbulation method employed at the Film Laboratory of Twentieth Century-Fox Film Corporation at Hollywood is disclosed and the various sensitometric means of control relative to this problem are given.

One of the many problems confronting the laboratory and sound technicians of the motion picture industry is the elimination of 96-cycle sprocket-hole modulation. The use of noise-reduction systems and the improvement in other aspects of recording and processing have made this problem daily more obvious and acute.

There are many and varied causes of sprocket-hole modulation. In general, they are: (1) variation in film-operating speed at sprocket-hole frequency in recording, printing, and projection; (2) variation in exposure during these operations due to reflections, *etc.*; and (3) variation of development around the sprocket-hole areas. Special cases due to abrasions and pressure occur now and then, but their causes and methods of prevention are well known.

The improvements in film-drive mechanisms in the recording machines and the adoption of the new type sound-heads in projection have reduced the 96-cycle modulation due to variation of film speed and exposure in recording and projection to the point where the major troubles remain in processing and printing. It is the purpose of this paper to show how, at the Twentieth Century-Fox Laboratories,

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\*Presented at the 1940 Fall Meeting at Hollywood, Calif.; received October 15, 1940.

\*\*Twentieth Century-Fox Film Corp., Hollywood, Calif.

sprocket-hole modulation resulting from development has been reduced to the point at which the 96-cycle component is inaudible in the ground-noise.

The first goal in attacking the problem was to find the simplest and most practicable method of measuring the results of our experiments. Frayne<sup>1</sup> had used successfully at least three methods in his investigation of the effect of the sprocket-holes upon development of the sound-track area, and in his comparisons of the processing conditions obtaining at the different film laboratories in Hollywood. With a flutter-measuring set he measured the frequency and amplitude modulation of a 3000-cycle wave, and by scanning the sound-track in 5-mil increments showed that the sprocket-holes produced a marked effect upon the development of the track over a distance of approximately 30 mils from the holes. Another method used was that of scanning an unmodulated track with a microphotometer, which gave substantially the same results. A further method successfully used was the scanning, by a microphotometer, of an exposure of square-wave characteristics. This test illustrated the advantages of some systems of turbulation of the developer.

The time-honored test of developing sensitometer strips in opposite directions was considered at Twentieth Century-Fox but was dropped as not being sufficiently critical. Comparison of equal exposures of different areas was tried and found to be of value in estimating the effectiveness of turbulation of the developer.

The most common testing methods employed were the measurement of the 96-cycle tone in an unmodulated track by running the track on a sound-head and measuring the signal through a band-pass filter with a volume indicator, and by comparing the densities and gammas as measured between the sprocket-holes and in the sound-track area. The latter test proved to be the most critical of all, and, as the measurements could be made in the film laboratory on existing equipment, was used to a great extent.

In describing these tests one might be led to think that some of the tests have no connection with sprocket-holes or sound-track areas. It must be remembered that directional effect and sprocket-hole modulation due to development are caused by the same thing and can be prevented by the same methods. Failure to remove the restraining products of development, that is, the soluble bromides, as fast as they reach the surface of the gelatin is the cause of these defects. Naturally, therefore, if it were possible to remove these

products before they could affect adjacent areas, there would be none of the aforementioned effects present. These effects are most serious in cases where a high gamma-infinity stock, such as sound-recording film, is developed to a low gamma.

It was evident that if the length of time that the exhausted developer was in contact with the film were lessened sufficiently, there would be no change in the result of development from the additional agitation of the sprocket-holes or from the directional effect. If the flow of developer on the surface of the emulsion could take place at a rate high enough to wash away the bromides and supply unexhausted developer before any deleterious effects were produced, then the ideal condition would have been reached.

In order to determine the rate of flow necessary to approximate this condition, a special developing machine was built, on which short lengths of film were developed. The speed of the drum carrying the film was controlled very definitely, so that the rate of flow of the developing solution over the surface of the emulsion, which ranged from zero to 1750 feet per minute, could be measured.

Exposures were made on the Eastman IIb sensitometer so that they could be read between the sprocket-holes as well as in the sound-track position (Fig. 1). The small dots are of identical exposure, and are of value when compared with the larger exposures in estimating the effectiveness of the removal of development products. The increase in density should be noted of the areas between the sprocket-holes due to the increased agitation of the developer. This film was travelling through the developer at a rate of 90 feet per minute and was processed under the conditions prevailing before the addition of the present system of turbulation.

Fig. 2 shows the relation between densities measured between the holes (broken curve) and in the sound-track area (solid curve), for the strip shown in Fig. 1. The separation between the curves is a direct measure of the amount of sprocket-hole modulation to be expected, inasmuch as it is this density difference that produces the 96-cycle modulation.

As the speed of the film through the developer is increased it is

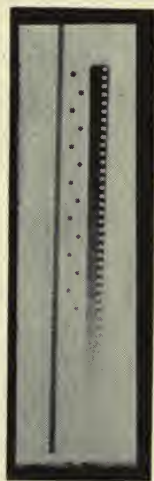


FIG. 1. Photograph of special sensitometer strip.



to be expected that the more complete development of the exposures due to increased agitation will result in greater density and contrast. Fig. 3 shows this to be a fact. The time of development was held constant and the speed of the film through the developer was varied from zero to 1750 feet per minute. The increase of gamma in the sound-track is shown by the solid curve and between the sprocket-holes by the broken curve. The fact that the broken curve begins to flatten at a lower film speed than the solid curve is evidence of a closer approach to ideal conditions, and is a result of increased agitation of the developer in the sprocket-hole areas.

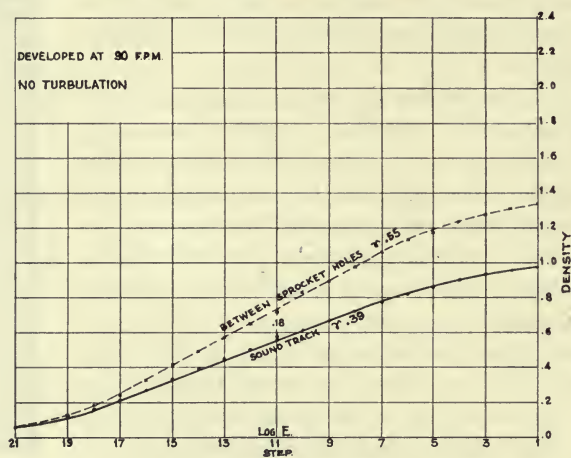


FIG. 2. Relation between densities measured between sprocket-holes (broken curve) and in the sound-track area (solid curve), for the strip shown in Fig. 1; developed at 90 fpm; no turbulation.

Fig. 4 shows the increase in density with increase in speed through the developer. The general characteristics of these curves are the same as those of Fig. 3. Note that above 700 feet per minute further increases of speed produce no appreciable difference in density between the holes. The exposure used for this measurement was the 11th step, which gives practically the same exposure as is required for the unbiased sound-track. The vertical distance between the curves is a measure of the 96-cycle modulation produced in development.

The difference in density between the sound-track area and the areas between the sprocket-holes is shown by Fig. 5. The tests at



various film speeds were developed to the same gammas. As can be seen, the maximum amount of sprocket-hole modulation occurs at speeds between 25 and 100 feet per minute. The worst conditions prevail at the very speeds at which the developing machines were designed to operate.

Many schemes were considered for increasing the agitation of the developer. The use of a trough with the developer running at high speed opposite to the film travel has been tried with some success

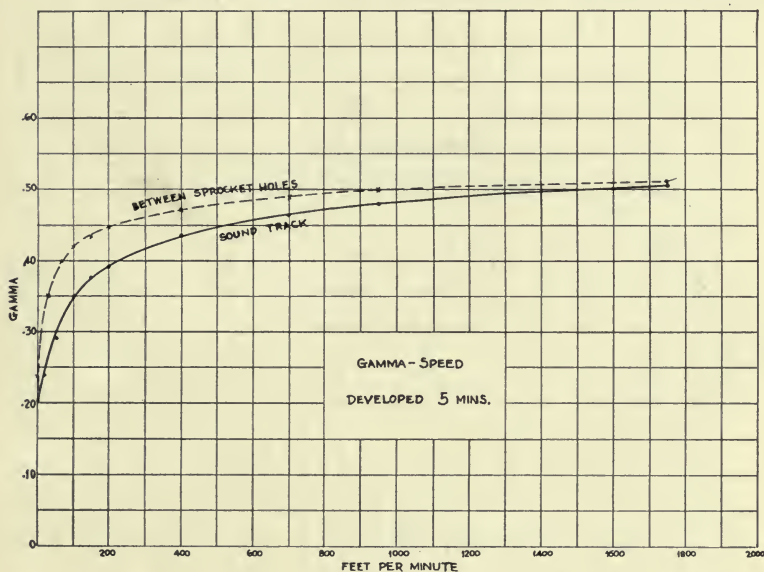


FIG. 3. Curves showing difference between gamma of areas between sprocket-holes (broken curve) and sound-track area (solid curve), as a function of film speed; developed five minutes; no turbulation.

but would have necessitated building new developing machines. Squeegees and brushes in contact with the emulsion have been used effectively in some "still" laboratories and might have value in conjunction with some types of developing machines. At Twentieth Century-Fox the Spoor-Thompson machine is used, in which the film runs vertically in long strands. Between the upper and lower rollers there is no support for the film and therefore no pressure may be applied to the film except possibly at the rollers, which would represent a very small part of the total footage in the developer and would not be very effective. Increasing the speed of the machine would be im-

practicable because of the risk of film breakage, which becomes great at speeds over 125 feet per minute. As mechanical agitation and greater machine speed were impracticable, we decided to try increasing the relative speed of the film by the use of some system of moving the developer across the film at a rapid rate. Spraying the film with developer forced through jets at considerable pressure probably would be the best way of removing the development products from the surface of the emulsion, but the problem of supporting the film against this pressure precluded the use of such a method.

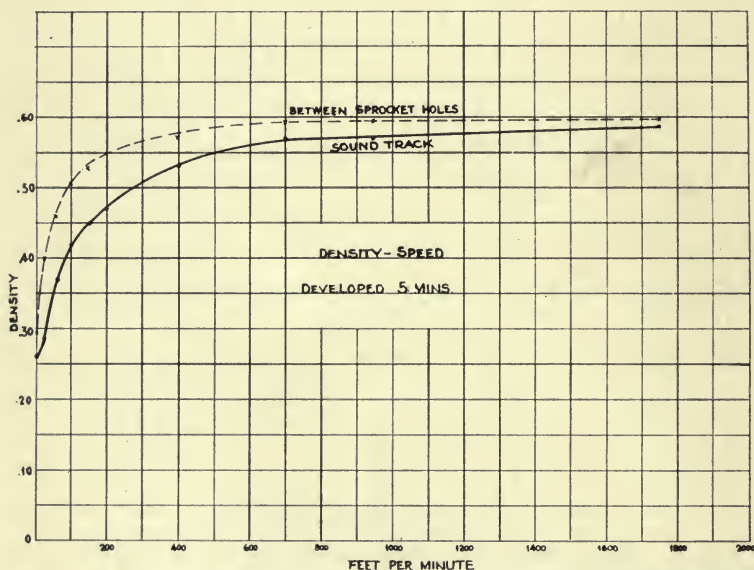


FIG. 4. Difference between density of areas between sprocket-holes (broken curve) and sound-track area (solid curve), as a function of speed of film; developed five minutes; no turbulation.

It was finally decided to try emptying the developing tanks and flowing the developer down the vertical strands of film. Header jets at low pressure were used for the purpose, allowing the developer to flow by gravity down the full length of the strand. It was realized that the relative speed of the developer over the film would not be sufficient to achieve the ideal state of turbulation under which there would be no difference between the densities around the sprocket-holes as compared with those in other areas. In order to minimize the directional effect, the developer was caused to flow down the film

in the direction of film travel as well as in the opposite direction. The rate of flow of developer through the jets was 250 gallons per minute per machine. Fig. 6 shows the arrangement of the jets and the flow of developer down the film. All our developing machines are now operating substantially as shown and described. Actually, the tanks are not completely empty. Sufficient developer is kept in the bottom of the tanks to provide lubrication for the lower rollers.

The results obtained with this method of development are surprisingly good. Fig. 7 represents the conditions as they exist using

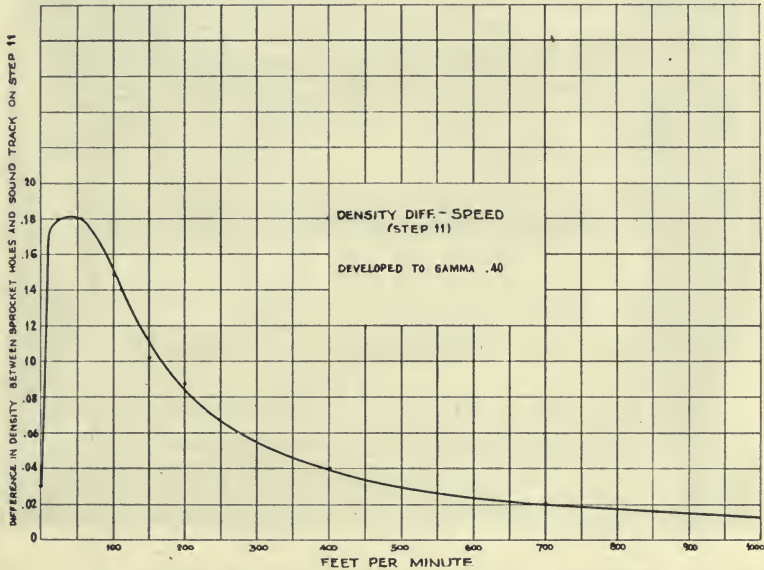


FIG. 5. Difference in density between sprocket-hole areas and sound-track area, as a function of film speed; developed to gamma 0.40.

the machines so modified. Note the small separation between the two curves as compared with the curves of Fig. 2, for the machine in its previous condition. There is still some difference between the curves but the measurements made between the holes represent the most extreme condition of turbulence to be found on the surface of the film. The difference in density at the 11th step now amounts to only 0.04, whereas with the old system the difference at that step was 0.18 (Fig. 2). Returning to Fig. 5, the differential of 0.04 that we now have is seen to be equivalent to the results obtained by



running the developing machine at a speed of 400 feet per minute. This result is now attained at a safe machine speed of only 90 to 100 feet per minute.

Electrical Research Products, Inc., in their investigations of processing conditions at the various laboratories in Hollywood have found that the Twentieth Century-Fox Laboratory is consistently good with respect to the negligible 96-cycle modulation present in the product. One of their tests is particularly interesting from the picture point of



FIG. 6. Photograph showing the arrangement of the jets and the flow of developer on the surface of the film.

view as well as the sound. This is the square-wave exposure referred to earlier in this paper. Fig. 8 was produced by scanning the block exposures with a microphotometer in a direction parallel to that in which the film was developed. The figure on the left was obtained from the tests processed at Twentieth Century-Fox Laboratories while that on the right was developed at the laboratories of another major studio. The right-hand figure exhibits very marked directional effects. Observe how the entering edge of the exposure is developed quite efficiently, and how the development of the rest of the block is restrained to a greater and greater degree as the soluble bromides are



dragged across the exposure. The sample developed by us shows practically no directional effect and considerably less Eberhard effect. The fact that the density at the edges of the exposure is closer to the density in the center of the exposure, and the underdeveloped areas adjacent to the high exposures are of less magnitude, makes it seem reasonable to assume that there is some reduction of the Eberhard effect. This assumption requires further investigation before it can be proved, and it is contrary to the expressed opinion of some

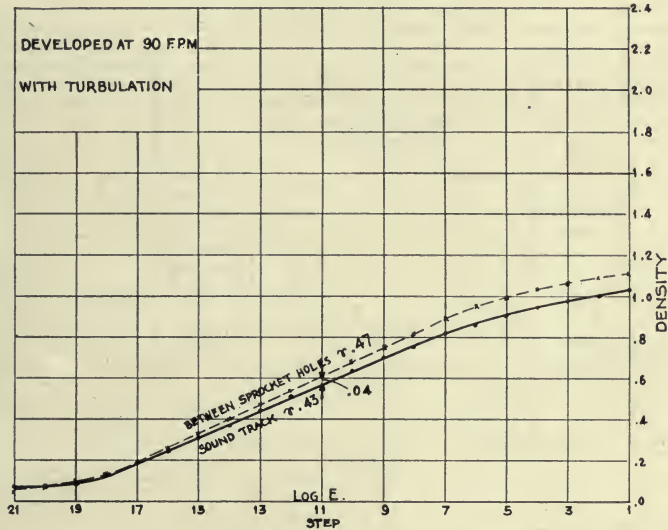


FIG. 7. Curves showing difference between density of areas between sprocket-holes (broken curve) and sound-track area (solid curve), developed at 90 fpm; with turbulation. (Compare with Fig. 2.)

experts in this line. It is our intention to continue investigations in this direction.

In order that the results of these tests may be comparable with directional tests made by other investigators, we present here the same type of test as used by J. Crabtree and J. H. Waddell<sup>2</sup> and others (Fig. 9). Sensitometer strips were developed in opposite directions in the developing machine under the present conditions and also under the original conditions. The machine speed in both cases was 90 feet per minute. The broken curve lines represent development with the high exposures leading. The negligible di-

rectional effect shown by the curves on the right, representing the conditions as they are at present is apparent.

In comparative measurements on a sound-head through a low-pass filter we find that the negative reproduces about 6 to 10 db less of the 96-cycle modulation with our present system than previously. This reduction is sufficient to eliminate development sprocket-hole modulation completely from the print so far as the ear is concerned. Only by eliminating ground-noise by the use of band-pass filters is it possible to measure the modulation now present.

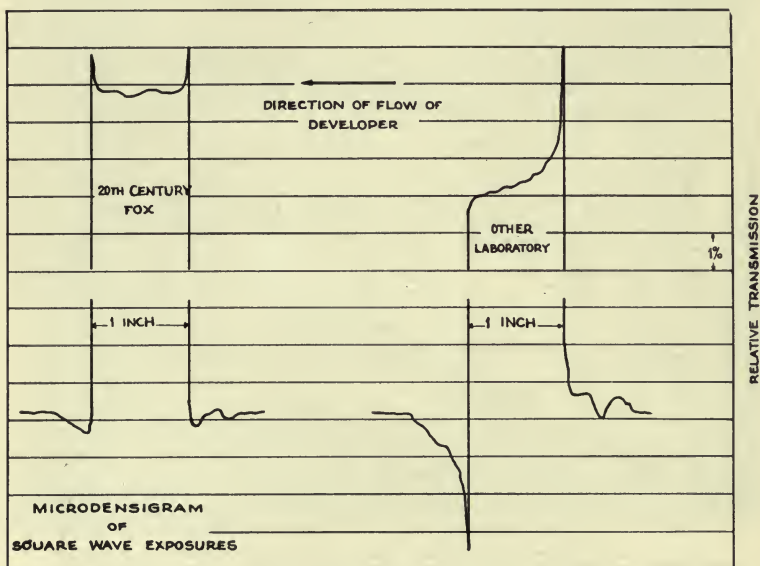


FIG. 8. Square-wave test: (left) From tests processed at Twentieth Century-Fox Laboratories, (right) from tests developed at laboratories of another major studio.

Many interested persons have asked about the comparative chemical costs with this method of turbulation. At first glance it would appear that, with the developer flowing through the air, the oxidation of the developing agents would be serious and that the resulting loss of developing power would require that larger quantities of the solutions be thrown away and more booster used, thus increasing the chemical costs materially. On the contrary, we found that the greatly increased efficiency of the developer, due to the more effective agitation, forced us to cut the quantity of developing agents to less

than half the original amount. Another factor is that aeration of a developer of low alkalinity containing hydroquinone has been found to increase the developing power to some extent. The rate at which used developer is discarded is about the same as before. A reasonable increase in the cost of processing would not have deterred us from using any methods resulting in an improvement in our product, but it was with some sense of satisfaction that this particular advance-

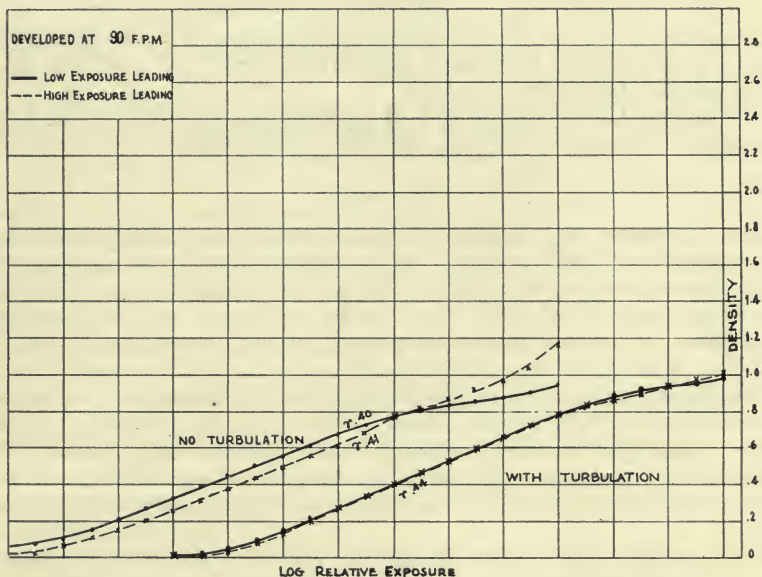


FIG. 9. Comparison of tests made with and without turbulence: (broken curves) strips developed with high exposures leading; (solid curves) strips developed with low exposures leading.

ment was achieved at no additional operating expense. As a matter of fact, the only difficulties which we have experienced are attributable to the small amount of chemicals in the solution. It is necessary to exercise somewhat closer control of time of development and addition of booster than was customary previously.

Although this paper primarily pertains to sound-track development, it will be obvious that the superior turbulence that resulted in the reduction of sprocket-hole modulation development will be effective in alleviating directional effects, Mackie lines, *etc.*, in the picture as well. Undoubtedly there is much room for further im-

provement of developing machines, as all machines at present fail to achieve ideal turbulation by a large margin. We are conscious of the fact that this is a rather makeshift arrangement and that by building an entirely new developing machine still better results could be achieved. As an addition to the Spoor-Thompson machine, however, we feel that the benefits derived are great enough to make it worthy of being brought to the attention of the Society.

#### REFERENCES

<sup>1</sup> FRAYNE, J. G., AND PAGLIARULO, V.: "The Influence of Sprocket-Holes upon the Development of Adjacent Sound-Track Areas." *J. Soc. Mot. Pict. Eng.*, XXVIII (March, 1937), p. 235.

<sup>2</sup> CRABTREE, J., AND WADDELL, J. H.: "Directional Effects in Sound-Film Processing," *J. Soc. Mot. Pict. Eng.*, XXI (Nov., 1933), p. 351.

#### DISCUSSION

MR. CRABTREE: Mr. Leshing and his co-workers are to be congratulated on this ingenious and simple method of increasing turbulation. It is an application of the scheme used by Friend Baker at the Warner Studios many years ago, the film being developed on a reel. The developer was poured over the reel across the surface of the film and the developer turned the reel in the manner of a water-wheel.

MR. DAILY: Is the sound negative developer agitation method applied also to the release positive developing machines?

MR. LESHING: We are not making any release prints here to any extent. We make only five or seven copies—so far as those are concerned, yes. I do not know exactly what method is being used in the DeLuxe Laboratories in the East.

MR. KELLOGG: This method of agitation permits greater motion of liquid over the sound-track than it does over the region between the sprocket-holes, because the sprocket-hole, when the flow is parallel to the film, is somewhat of an obstruction.

The question occurs as to whether there might not be too much oxidation of the developer, with it continually flowing over the surface of the film.

MR. CRABTREE: About six months ago we published a paper in the JOURNAL dealing with the effect of excessive aeration of developers, and the types used were surprisingly resistant to aerial oxidation.

In the case of developers containing hydroquinone, sodium hydroxide is formed as a by-product of oxidation, so that the activity of the developer increases. In the case of developers containing metol, there is no such effect, but if the activity of the developer falls off it is simply a matter of adjusting the rate of replenishment to compensate for any slight change in activity.

MR. KELLOGG: I am familiar with the method of agitation by sending air bubbles through the developer. But allowing the developer to flow down the film in thin surface streams might expose it to the air a great deal more than the bubble system.



I would be interested in knowing whether it is a question of degree of oxidation, or whether the developer simply refuses to be oxidized any more due to some kind of exhaustion or saturation effect.

MR. LESHING: We have never made any measurements of the rate of oxidation. However, any fears that we may have had that the developer would oxidize or would not stand up, or that we should have to use extremely strong formulas, were dispelled with the first test. We tried all kinds of jets—flat, round, and of different sizes—but found nothing to indicate that the rate of oxidation is greater with one form of turbulation than with any other.

MR. CRABTREE: Do you have any difficulty due to excessive foaming of the developer, or do you use an anti-foaming agent?

MR. LESHING: We use some; not much.

MR. SCOVILLE: This matter of turbulation goes much further than merely improving the 96-cycle modulation, and affects to a marked extent the choice of optimum processing conditions for variable-density sound.

As an example, if dynamic recording tests are made and the film is developed at Fox, the optimum print and negative densities determined thereby are very nearly the same as would be expected from the sensitometric data. Also, there is good correlation between the indications of various types of distortion tests, such as delta-db tests, intermodulation tests, and harmonic tests. With film developed at other Hollywood laboratories no such correlation is generally obtained.

The question was brought up a while ago as to why a dynamic recording test does not indicate the same optimum as the sensitometer test. Such investigations as I have made indicate that directional effect and lack of adequate turbulation are usually responsible for that difference.

DR. FRAYNE: In our tests of sound-track development we have always found in the Fox Laboratories less 96-cycle modulation, less directional effect, and also the best correlation between sensitometric control and other tests such as Mr. Scoville has pointed out.

I hope that this paper will stimulate other laboratories to do as good a job in this regard as Mr. Leshing has accomplished.

## A NEW MIRROR LIGHT-MODULATOR\*

W. R. GOEHNER\*\*

*Summary.*—A vibrating mirror light-modulator developed for 200-mil push-pull recording is described. Modern magnetic materials are used in the magnetic structure to obtain high electromagnetic efficiency and therefore adequate electromagnetic damping. Distortion is limited to low values by accurate mechanical balance of the armature. An inverse shunting network, to build the modulator impedance out to a constant resistance, has been developed, making the response characteristic substantially free from driving-circuit impedance, so that any desired frequency characteristic can be obtained by the insertion of a constant-resistance equalizer.

The technic of recording sound on film involves a series of conversions from one form of energy to another. The first step is the conversion of the acoustic energy of the sounds to be recorded into electrical energy. The final step, a chemical one, produces a metallic silver strip which should be, if the complete process is correct, an exact record of the instantaneous variations of the original acoustic energy. Since there are several stages in this conversion process, the possibility exists at each stage that the new form of energy will not be a true copy of the original. Much of the development work that has been carried on since the introduction of the sound-on-film method for commercial sound pictures has been directed toward the objective of reducing to very low values any remaining distortion in each step of the process. Comparison of present-day recording quality with some of the early recordings gives ample evidence of the progress that has been made in the entire process—from microphone to the final image on the film, and from film to the re-created sound in the theater. The present state of the art, therefore, imposes quite severe requirements on new equipment, especially when further improvements in overall quality are desired. Consideration of these requirements led Electrical Research Products engineers to the use of 200-mil push-pull variable-area sound-track for prime

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\* Presented at the 1940 Meeting at Hollywood, Calif.; received Oct. 10, 1940.

\*\* Bell Telephone Laboratories, New York, N. Y.

recordings as a direct means of improving the overall sound quality of the release print. To accomplish this objective, it became evident that a new recording system, including an improved light-modulator, would be required if the full advantage of the proposed recording method were to be realized. This paper describes the vibrating-mirror modulator developed for this system by the Bell Telephone Laboratories.

The optical system for push-pull recording, as shown by Fig. 1, was designed to use a mirror  $6.7 \times 10.0$  mm. With this arrangement, a deflection of approximately  $\pm 0.3$  degree will modulate both tracks to the 100 per cent value. It is evident that a smaller mirror placed closer to the recording slit can be adjusted to pass the required light flux, but greater amplitude will be necessary to produce 100 per cent modulation.

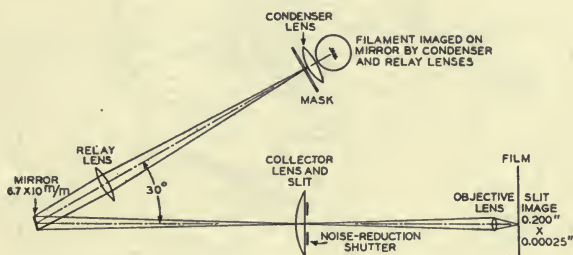


FIG. 1. Optical system.

In the selection of an electromechanical driving system that would rotate the rather large mirror through the required angular distance, the Laboratories' experience in other fields was drawn on rather heavily. Although the Laboratories had not previously developed a vibrating-mirror light-modulator for use in film recording, it was found that many devices developed for other purposes, such as galvanometers, oscillographs, relays, and receivers had features that could be directly applied to this light-modulator problem. Practical experience with some of these structures influenced the selection of a mechanical coupling to the mirror that would eliminate the possibility of lost motion between the applied torque and the motion of the mirror. The necessity for this precaution is evident when it is realized that the amplitude of the end of the mirror at 100 per cent modulation is only  $1/400$  of the 6.7-mm dimension, or approximately 0.0007 inch. After some preliminary tests, a balanced

magnetic structure,<sup>1</sup> basically capable of design for very low magnetic distortion, was selected as offering the best possibility of meeting the mechanical and electrical distortion limits.

A cross-section of the magnetic structure is shown in Fig. 2. The mirror is mounted directly on the removable armature, shown in Fig. 3. The torque to drive the mirror is obtained along the edge of the armature by the magnetic pull over the pole-tips. The pole-pieces are built up from laminations of the shape shown in Fig. 3.

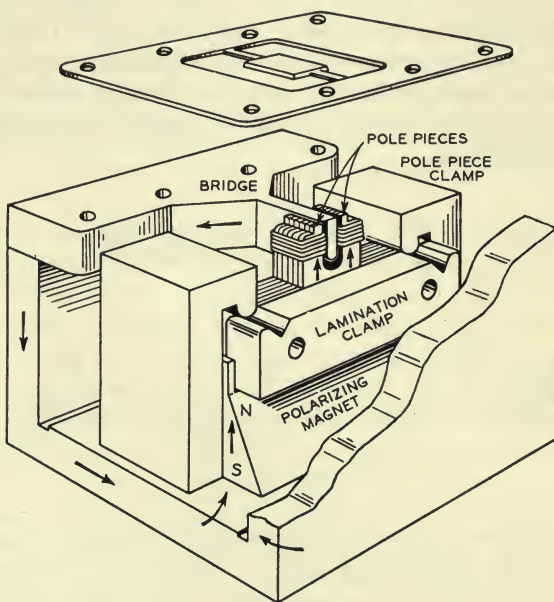


FIG. 2. Magnetic structure with armature removed.

These laminations are securely clamped by two grooved bars, one of which is shown in Fig. 2. The pole-piece assembly is held against the permanent magnet by the non-magnetic centering clamps. The steel screws holding these clamps pass through clearance holes, permitting accurate centering of the pole-pieces with respect to the bridge. The armature, with its torsion supports and frame, is milled from a single piece of metal; it rests on spacers and the tensioned tungsten wire shown in Fig. 3. The tungsten wire serves the two-fold purpose of accurately determining the air-gap and at the same time providing a precision, line-contact bearing surface of extreme



hardness. Both sides of the armature are lapped and polished to provide a satisfactory mounting for the mirror. The coils are layer-wound, permitting the coils to fit into the small space left between the bridge and the edge of the pole-pieces. As shown in Figs. 2 and 3, the path of the steady flux from the permanent magnet is through the pole-tips to both sides of the armature, passing through the armature to the center above the bridge, leaving the armature above the tungsten wire to the bridge, and out both sides of the bridge, returning to the base of the permanent magnet through the U-shaped supporting structure. The signal windings placed around the pole-pieces are connected so that the flux due to the signal currents aids the steady flux in one gap and opposes it in the other,

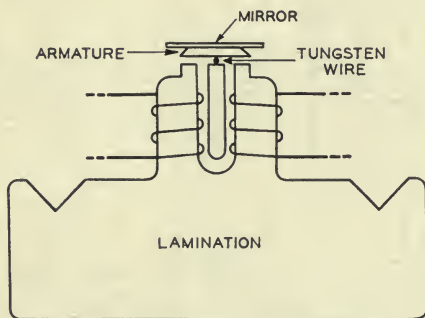


FIG. 3. Pole-piece and armature.

thereby causing the mirror to oscillate in accordance with the direction and magnitude of the signal current. Since one side of the armature approaches the pole-piece when the other side of the armature is receding, the total air-gap remains constant. With this type of structure, the second-harmonic distortion is balanced out if the mechanical structure is balanced; for this reason considerable care was taken to make the structure symmetrical about the rotational axis. Since the mechanical balance may not be perfect, the remaining distortion can be minimized by designing the magnetic circuit to reduce the initial value of the distortion caused by each gap.

The design of the magnetic circuit to minimize the magnetic distortion is very similar to the design of vacuum tube amplifier circuits, where the non-linear relation between plate current and grid voltage can be made to yield, for a limited voltage range, any degree

of linearity, depending upon what elements are connected in the circuit. In amplifier design experience, it has been found that less than 1 per cent distortion can not be heard under optimum conditions of listening with wide-frequency band systems. If the recording-reproducing process were developed to the ideal limit, it might

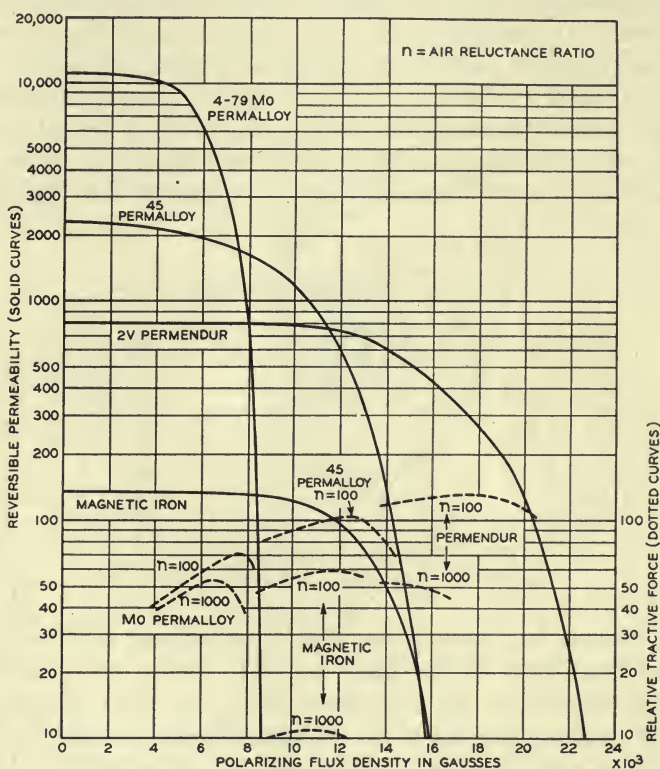


FIG. 4. Reversible permeability vs. polarizing flux density.

be desirable to hold the distortion in light-modulators to this value or less. However, film as a recording medium has some non-linear distortion by itself, as evidenced by cross-modulation and development effects. For this reason, it does not seem profitable at the present time to reduce the modulator distortion to less than the overall film development effects. This modulator was designed to limit the harmonic distortion to 2 per cent for full modulation. At lower modulations, the relative level of the harmonics decreases rapidly

to less than the 1 per cent value. If lower harmonic levels are required by future improvements in the film characteristics, the same design principles can be applied to meet the new limits.

In addition to the requirements of amplitude, mirror size, and low harmonic distortion, three other objectives were established: (1) the frequency response should be flat to 8000 cycles, (2) the damping should be adequate to prevent noticeable "overhang," and (3) the sensitivity should be high enough to permit operation from existing amplifiers. These three requirements are interrelated and directly dependent upon the electromechanical efficiency of the

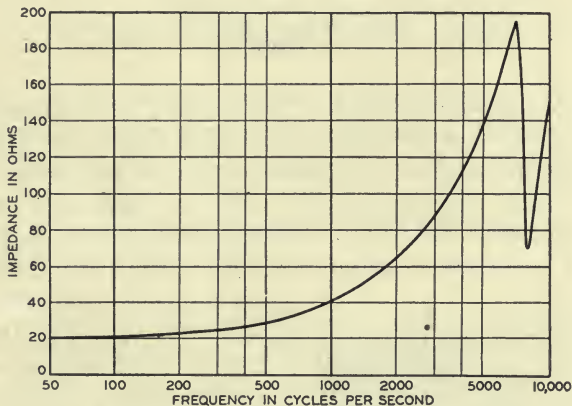


FIG. 5. Impedance of modulator.

torsional motor. It can be shown that in the ideal case the torque developed by this type of motor is

$$T = \frac{N A W B_0}{d} I$$

- $A$  = Area of pole-piece
- $W$  = Width of armature
- $B_0$  = Polarizing flux
- $d$  = Air-gap
- $N$  = Turns on coil
- $I$  = Current

This equation is based upon the assumption that air-gap reluctance is very large compared to the iron-path reluctance and that all the flux due to the current  $I$  links the air-gap. If these conditions ap-

plied to a practical design, it would be desirable to make  $B_0$  as large as possible and the air-gap as small as is practicable. As might be expected, the ideal case does not apply fully, the difficulty being that the reluctance of the iron circuit can not be made small enough

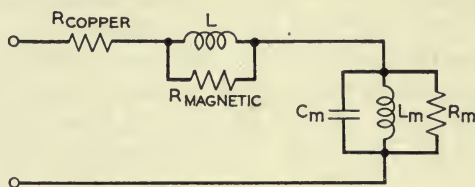


FIG. 6. Approximate equivalent circuit of modulator.

and, further, that the reversible permeability of the magnetic material is a function of the superposed steady flux. The effect of this factor upon the efficiency of polarized motor structures has been shown to reach a maximum at a value of superposed steady flux that depends upon the choice of magnetic design and magnetic materials.<sup>2</sup> These data are shown in Fig. 4, which shows that the modern magnetic materials are superior in regard to the magnitude of reversible permeability in the presence of high polarizing flux densities. In particular, both permendur and 45 perm-alloy are shown to be superior to the older magnetic materials. Permendur, offering the highest force factor and, therefore, the highest electromagnetic damping and efficiency, was selected for use in the parts of the circuit

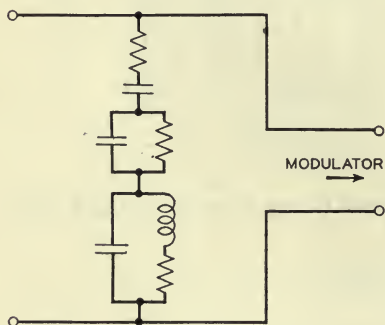


FIG. 7. Configuration of constant-impedance network.

carrying high flux density, *i. e.*, the armature, pole-pieces, and bridge. The impedance of the modulator, as shown in Fig. 5, can be represented approximately by the circuit arrangement shown in Fig. 6; the values of the circuit elements can be determined from the impedance data.<sup>3</sup> Once the values of the equivalent network are determined, a shunting network of a type developed to equalize a telephone receiver can be designed to make the load impedance

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looking into the modulator constant.<sup>4,\*</sup> Fig. 7 shows the configuration of this network. Fig. 8 shows the impedance of the modulator when connected to a constant-impedance network of the type shown in Fig. 7. The maximum impedance variations are reduced to the

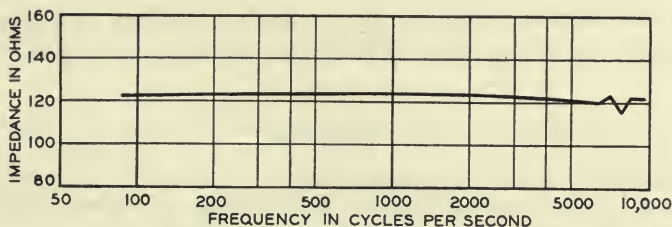


FIG. 8. Modulator impedance with constant-resistance network.

order of 4 per cent and the average, over the major part of the frequency range, is approximately  $\pm 1$  per cent. This means that the response characteristic of the modulator is made substantially independent of the driving-circuit impedance and that any desired response can be predicted and obtained by the insertion of an equalizer of the constant-resistance type.

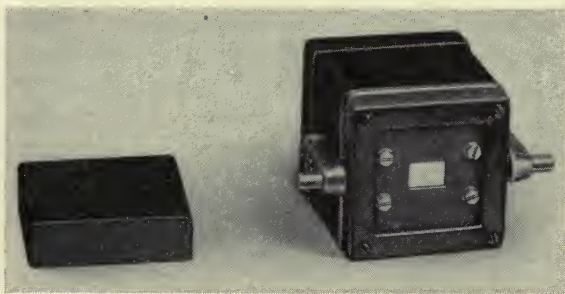


FIG. 9. Variable-area modulator.

In addition to the electrical, mechanical, and magnetic problems, considerable attention was given to the optical quality of the mirror surface. The mirror surface was worked to the flatness limits required by the optical system. To insure maintenance of the optical flatness of the mirror when mounted on the armature, a special

\* Modulator network designed by E. L. Norton.

cementing technic was developed. Overall distortion of less than one wavelength (0.00002 inch) from a true surface has been found practicable. The mirror surface is aluminum, evaporated onto the highly polished front surface of the glass, providing a mirror of high reflecting power well into the ultraviolet region.

The overall dimensions of the modulator mounted in its case are  $1\frac{3}{4} \times 1\frac{3}{4} \times 2\frac{1}{16}$  inches. Fig. 9 is a photograph of the assembled unit.

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- <sup>3</sup> WEGEL, R. L.: "Theory of Magneto-Mechanical Systems as Applied to Telephone Receivers and Similar Structures," *J. A. I. E. E.*, **XL** (Oct., 1921), p. 791.
- <sup>4</sup> JOHNSON, K. S.: "Transmission Circuit for Telephonic Communication," *D. Van Nostrand & Co.* (1927), p. 237.

## SCANNING THEORY\*

S. SABAROFF\*\*

*Summary.*—Scanning, or probing, is fundamental to most objective investigation. A spatial scanning theory applicable to a space of any number of dimensions is described in which the relation between the field being scanned and the scanned output is expressed in terms of a scanning operator, or function. The relation between the probe qualities and the scanning operator can be expressed by means of Fourier's Integral Theorem so that either may be derived from the other. Examples of the application of the theory to record film and television scanning are discussed.

The theory of scanning has been considered by a number of authors. The approach has, in general, been with respect to specific applications in which the process of scanning has not been greatly differentiated from the kind of thing scanned.

Scanning in itself is fundamental to most objective investigation. Thus the determination of a physical quantity ordinarily involves the use of a scanner or probe of some kind in which the effect upon the probe is taken as a measure of the quantity under investigation.

It is evident that in general the process of scanning or measuring will give a result that is a kind of average of the region occupied by the probe, thus giving rise to an error in the resultant measurement. The magnitude of this error depends, in part, upon the relative dimensions of the probe and the region of which a measurement is desired.

In this paper an attempt will be made to present a fundamental theory from which the various scanning relations can be derived as a natural consequence.

### ONE-DIMENSIONAL THEORY

Suppose for the moment that the region under consideration is one-dimensional and that its state can be represented by the scalar function  $f(x)$ . This field is to be thought of as being contained in a line, with a line segment as the probe or scanner.

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\* Received January 1, 1941.

\*\* WCAU Broadcasting Co., Philadelphia, Pa.

The resulting measurement is proportional to a combination of the segment field and the field that the probe covers. The manner in which these fields combine depends upon their nature. It will be assumed throughout that the resultant field at any point is proportional to the product of their values at that point.

A representation of this kind of arrangement is shown in Fig. 1, in which the segment field is shown graphically as an extension at right angles to the segment in the plane of the paper.

The effective field  $F(x)$  included by the line segment is

$$F(x) = \int_{\text{SEG}} P(\alpha)f(x + \alpha)d\alpha \quad (1)$$

where  $P(\alpha)$  is the segment field and the integration is to be taken over the length of the segment.

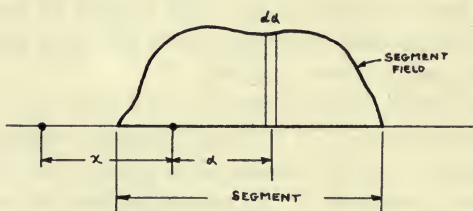


FIG. 1. One-dimensional representation.

Consider the expression

$$f_1 = f(x + \alpha) \quad (2)$$

and expand it in a Taylor series in  $\alpha$ ,

$$f_1 = f(x) + \frac{\alpha}{1!} \frac{\partial f(x)}{\partial x} + \frac{\alpha^2}{2!} \frac{\partial^2 f(x)}{\partial x^2} + \dots \quad (3)$$

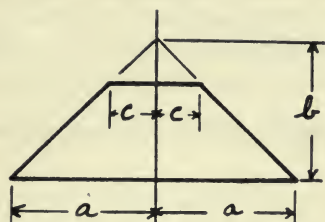
Writing  $p = \frac{\partial}{\partial x}$ , equation 3 becomes, symbolically,

$$f_1(x) = \left(1 + \frac{\alpha p}{1!} + \frac{\alpha^2 p^2}{2!} + \dots\right) f(x) = e^{\alpha p} f(x) \quad (4)$$

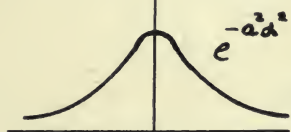
where  $e^{\alpha p}$  is a transfer operator that shifts  $f(x)$  a distance  $\alpha$  along the  $x$  axis.



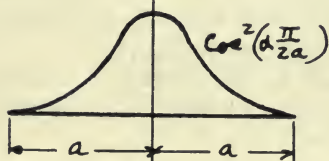
## Scanning Operator



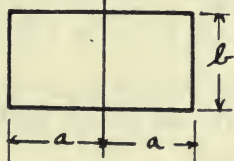
$$T(p) = \frac{2b}{ap^2} [\cosh (ap) - \cosh (cp)]$$



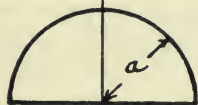
$$T(p) = \frac{\sqrt{\pi}}{a} e^{p^2/4a^2}$$



$$T(p) = \frac{\pi^2}{p(\pi^2 + a^2 p^2)} \sinh (ap)$$



$$T(p) = \frac{2b}{p} \sinh (ap)$$



$$T(p) = \frac{\pi a}{p} I_1(ap)$$

FIG. 2. Table of scanning operators.

Putting  $f(x + \alpha)$  in the operational form in equation 1 results in

$$F(x) = \left[ \int_{\text{SEG}} P(\alpha) e^{j\alpha p} d\alpha \right] f(x) \quad (5)$$

where the bracketed expression in equation 5 is an operator acting on  $f(x)$ .

Let

$$T(p) = \int_{\text{SEG}} P(\alpha) e^{j\alpha p} d\alpha \quad (6)$$

Then equation 5 is

$$F(x) = T(p)f(x) \quad (7)$$

The evaluation of  $T(p)$  from equation 6 is an ordinary integration with the operator  $p$  regarded as a constant. The expression  $T(p)$  could be termed the scanning operator or scanning function, since its form is determined solely by the qualities of the scanning segment. A short table of scanning functions for some segment distributions<sup>1,2</sup> that have appeared in the literature is shown in Fig. 2.

Ordinary operational methods<sup>3,4</sup> hold for the solution of equation 7. An important application is when  $f(x)$  is periodic in  $x$ . If the frequency in  $x$  is  $p_1$ , the substitution of

$$p = jp_1 \quad (8)$$

in equation 7 will give the complete solution. Equation 8 is utilized when the field being scanned is given in the form of a Fourier series or a Fourier integral.

Another useful aspect of the operational method is the property of inversion. If in equation 7,  $F(x)$  and  $T(p)$  are known, then  $f(x)$  is

$$f(x) = T^{-1}(p)F(x) \quad (9)$$

where now the operator  $T^{-1}(p)$  is taken as acting on  $F(x)$ . Thus the influence of the segment in  $F(x)$  can be cancelled by an application to it of the inverse of the scanning operator.

The use of Fourier's Integral Theorem enables the determination of the segment field distribution for a given form of  $T(jp_1)$ .

Rewrite equation 6 so that

$$T(jp_1) = \int_{-\infty}^{+\infty} P(\alpha) e^{j\alpha p_1} d\alpha \quad (10)$$

where  $jp_1$  has been substituted for  $p$ . The length of the segment has been taken as extending through plus and minus infinity since the field can be considered as zero outside of the actual segment extent.

Equation 10 is a Fourier transform.<sup>5</sup> Its mate is

$$P(\alpha) = \frac{1}{2\pi} \int_{-\infty}^{+\infty} T(jp_1) e^{-j\alpha p_1} dp_1 \quad (11)$$

thus giving the required segment field distribution.

Examples illustrating the use of one dimensional theory are considered in detail in Appendix 1.

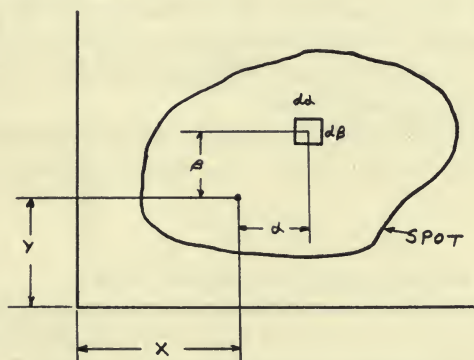


FIG. 3. Two-dimensional representation.

#### TWO-DIMENSIONAL THEORY

The discussion thus far has been concerned with a one-dimensional theory. The theory for two dimensions can be similarly set forth.

Let the field under consideration be represented by the scalar field function  $f(x, y)$ . This field is to be scanned or investigated by means of a probe in the shape of a spot having a certain area and a field function given by  $P(\alpha, \beta)$ .  $\alpha$  and  $\beta$  are measured from a point of reference on the spot having the coördinates  $x$  and  $y$ .

The scanning spot is supposed to lie on the field being scanned. A representation of this kind of an arrangement is shown in Fig. 3.

The effective field  $F(x, y)$  included by the spot area is

$$F(x, y) = \iint_{\text{SPOT}} P(\alpha, \beta) f(x + \alpha, y + \beta) d\alpha d\beta \quad (12)$$

By methods similar to those used in the derivation of equation 4, the operational form for  $f(x + \alpha, y + \beta)$  can be shown to be

$$f(x + \alpha, y + \beta) = e^{\alpha p + \beta q} f(x, y) \quad (13)$$

where  $q = \frac{\partial}{\partial y}$ .

Equation 12 can then be written as

$$F(x, y) = T(p, q)f(x, y) \quad (14)$$

where the scanning function is

$$T(p, q) = \int \int_{\text{SPOT}} P(\alpha, \beta) e^{\alpha p + \beta q} d\alpha d\beta \quad (15)$$

As in the one-dimensional case, the evaluation of  $T(p, q)$  from equation 15 is an ordinary integration with the operators  $p$  and  $q$  regarded as constants.  $T(p, q)$  may then be applied to  $f(x, y)$  in accordance with the usual operational theory.

Of special importance is the case when  $f(x, y)$  is periodic with a frequency in  $x$  of  $p_1$  and in  $y$  of  $q_1$ . The substitution of

$$\left. \begin{aligned} p &= jp_1 \\ q &= jq_1 \end{aligned} \right\} \quad (16)$$

in equation 14 will then give the complete solution.

The use of Fourier's Integral Theorem for two variables enables the determination of the proper spot field distribution for a given form of  $T(jp_1, jq_1)$ .

Rewrite equation 15 so that

$$T(jp_1, jq_1) = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} P(\alpha, \beta) e^{j\alpha p_1 + j\beta q_1} d\alpha d\beta \quad (17)$$

where  $jp_1$  and  $jq_1$  have been substituted for  $p$  and  $q$ , and the limits extended to plus and minus infinity.

Equation 17 is a Fourier transform for two variables. Its mate is

$$P(\alpha, \beta) = \frac{1}{4\pi^2} \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} T(jp_1, jq_1) e^{-j\alpha p_1 - j\beta q_1} dp_1 dq_1 \quad (18)$$

thus giving the required spot field distribution.

Solutions for fields that vary in two dimensions are not usually simple. In most practical applications, however, the scanning spot has circular symmetry, thus eliminating spot orientation complexities. The expression for  $T(p, q)$  for this case is not difficult to derive.

The element of area for circular symmetry can be taken as  $s ds d\theta$  where  $\alpha = S \cos(\theta)$  and  $\beta = S \sin(\theta)$ . If the spot field is  $P(S)$  at a radial distance  $S$ , then equation 15 becomes



$$T(M) = \int_0^{+\infty} \int_0^{2\pi} \bar{S}P(S) e^{SM \cos(\theta - \phi)} dS d\theta \quad (19)$$

where  $M = \sqrt{p^2 + q^2}$ ,  $\cos(\phi) = p/M$  and  $\sin(\phi) = q/M$ .

Integrating equation 19 with respect to  $\theta$  gives finally

$$T(M) = 2\pi \int_0^{\infty} \bar{S}P(S) I_0(SM) dS \quad (20)$$

where  $I_0(SM)$  is a modified Bessel's function of the first kind and zero order.

When  $jM_1$  is substituted for  $M$  in equation 20, it becomes a Fourier Bessel Transform,<sup>6</sup> thus

$$T(jM_1) = 2\pi \int_0^{\infty} \bar{S}P(S) J_0(SM_1) dS \quad (21)$$

where  $J_0(SM_1)$  is an ordinary Bessel's function of the first kind and zero order.

The mate of equation 21 is

$$P(S) = \frac{1}{2\pi} \int_0^{\infty} M_1 T(jM_1) J_0(SM_1) dM_1 \quad (22)$$

thus enabling the determination of the spot field distribution for a given form of  $T(jM_1)$ .

An example illustrating the application of two-dimensional theory is briefly discussed in Appendix 2.

### THREE-DIMENSIONAL THEORY

As yet no need of a scanning theory for more than two dimensions has presented itself. It must be pointed out, however, that the above theory can be extended to include a space of any number of dimensions.

For example, in the case of three dimensions, the probe may be thought of as a speck moving about in the region under investigation. If the field of the speck alone is  $P(\alpha, \beta, \gamma)$  and the field being scanned is  $f(x, y, z)$ , then the effective field enclosed by the scanning speck is

$$F(x, y, z) = \iiint_{\text{SPECK}} P(\alpha, \beta, \gamma) f(x + \alpha, y + \beta, z + \gamma) d\alpha d\beta d\gamma \quad (23)$$

Operationally equation 23 can be written

$$F(x, y, z) = T(p, q, r) f(x, y, z) \quad (24)$$

The scanning function is

$$T(p, q, r) = \int \int \int_{\text{SPECK}} P(\alpha, \beta, \gamma) e^{\alpha p + \beta q + \gamma r} d\alpha d\beta d\gamma \quad (25)$$

where  $r = \frac{\delta}{\delta z}$ ,  $\gamma$  is the probe coördinate in the direction of  $z$ , and the other symbols remain the same as before.

Equations 23, 24, and 25 may be written concisely by changing to vector notation. Let  $x, y$ , and  $z$  be the components of the position vector  $R$ , and  $\alpha, \beta$ , and  $\gamma$  the components of the position vector  $\epsilon$ , then equation 23 becomes

$$F(R) = \int_{\text{SPECK}} P(\epsilon) f(R + \epsilon) dv \quad (26)$$

where  $dv$  is a differential volume and  $P(\epsilon)$  and  $f(R + \epsilon)$  are scalar field functions.

Operationally, 26 is

$$F(R) = T(\nabla) f(R) \quad (27)$$

The scanning function is

$$T(\nabla) = \int_{\text{SPECK}} P(\epsilon) e^{\epsilon \cdot \nabla} dv \quad (28)$$

where  $\nabla$  is a vector differential operator of space<sup>7</sup> and  $\epsilon \cdot \nabla$  is the scalar product of  $\epsilon$  and  $\nabla$ .

Disregarding the practicability of the matter, a complete three-dimensional scanning theory can be built up by the use of equations 23 to 28, inclusive.

#### CONCLUSION

The theory just outlined has been presented from a purely spatial point of view in which the only variable factor was the position of the scanning probe with respect to the field being scanned. Residual effects have been taken as being entirely absent; that is, the past history of a scanning operation has been assumed as not affecting either the present or the future scanned output.

In certain applications, the field scanned and the position of the scanning probe are both functions of time.<sup>8</sup> Ordinarily the probe size is small and the velocity of the scanning probe is so great that the

field being scanned does not vary appreciably during a scanning operation. This allows the application of the theory as an approximation.

In television, which bases its operation upon the integrating characteristics of the eye, the past history of a scanning operation, and the probe field and size are of extreme importance. These are qualities that affect the fine structure and definition of television images.<sup>1</sup> The theory may easily be modified in its application when these matters are considered.

Another application of the scanning theory is that it forms the basis of a spatial filter theory that is somewhat analogous to electrical filter theory. An example of such an application is considered in some detail in Appendix 1.

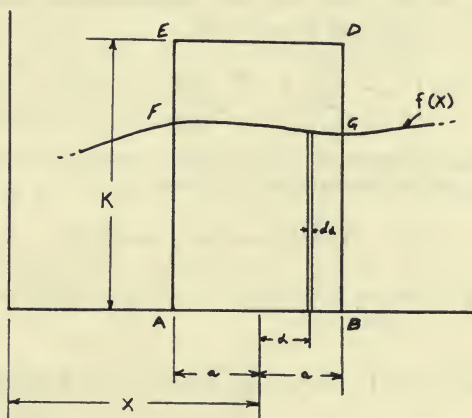


FIG. 4. Rectangular scanning beam.

## Appendix 1

### EXAMPLE OF ONE-DIMENSIONAL ANALYSIS

The reproduction of sound from a film record utilizes the relative motion of a rectangular beam of light and a film of variable area or density. The light passing through the film generates an electric current in a photocell which is brought to a desired level by means of amplifiers. It is of paramount importance to know the relation between the transmissivity of the film, the dimensions of the light-beam and the amount of light transmitted. This problem, in which the transmissivity has been assumed to vary in a periodic manner, has been treated at length in the past.<sup>9,10</sup> It will here be considered in the light of the foregoing theory.

In Fig. 4, the scanning beam of semiwidth  $a$  and height  $K$  is represented by  $ABDE$ , the measure of film transmissivity is denoted by  $f(x)$ , the amount of light transmitted is measured by the area  $ABFG$ , and the relative position of the beam and film is given by  $x$ .

The scanning function is

$$T(p) = K \int_{-a}^{+a} e^{\alpha p} d\alpha \quad (29)$$

where  $P(\alpha)$  has been taken as equal to a constant  $K$ .

Performing the integration in equation 29 gives

$$T(p) = \frac{K}{p} (e^{ap} - e^{-ap}) = \frac{2K}{p} \sinh (ap) \quad (30)$$

The form of  $f(x)$  has not yet been specified. If it can be represented by a Fourier's series with a fundamental frequency of  $p_1$ , thus

$$f(x) = A_0 + \sum_1^{n=\infty} A_M \cos (np_1x + \theta_n) \quad (31)$$

where  $A_n$  and  $\theta_n$  are the usual Fourier coefficients, then the application of equations 30 to 31 gives the well known result,

$$F(x) = 2Ka \left[ A_0 + \sum_1^{n=\infty} A_M \frac{\sin (anp_1)}{anp_1} \cos (np_1x + \theta_n) \right] \quad (32)$$

where the frequency of the constant term is taken as zero.  $f(x)$  may be discontinuous, and representable by the Fourier integral

$$f(x) = \int_0^{\infty} A(p_1) \cos [p_1x + \phi(p_1)] dp_1 \quad (33)$$

In the interval  $dp_1$ , equation 33 is periodic in  $x$  with a frequency  $p_1$ . Application of equations 30 to 33 therefore gives

$$F(x) = 2Ka \int_0^{\infty} A(p_1) \frac{\sin (ap_1)}{ap_1} \cos [p_1x + \phi(p_1)] dp_1 \quad (34)$$

a result that has been arrived at in another way by Horton and Mathes.<sup>11</sup>

Equation 30 may be expanded in powers of  $p$ :

$$T(p) = 2Ka \sum_{n=1,3,5}^{\infty} \frac{(ap)^{n-1}}{n} \quad (35)$$

which when applied to  $f(x)$  results in

$$F(x) = 2K \sum_{n=1,3,5}^{\infty} \frac{a^n}{n} \frac{d^{n-1}f(x)}{dx^{n-1}} \quad (36)$$

Equation 36 is a form especially useful when  $f(x)$  is given in the form of a series in  $x$ .

In a certain densitometric application, a continuous density range can be scanned by means of a rectangular light-beam in order to obtain a measure of the variation in relative transmissivity. Obviously, any non-linearity in the density variation will cause a distorted relation by virtue of the aperture effect.  $F(x)$  and  $T(p)$  are therefore known and it is required to find  $f(x)$ .



Operationally the problem is

$$f(x) = T^{-1}(p)F(x) \quad (37)$$

where, from equation 30,

$$T^{-1}(p) = \frac{p}{2K} \operatorname{csch}(ap) \quad (38)$$

When  $F(x)$  is analyzed in terms of a Fourier series such as equation 31, the solution is immediately

$$f(x) = \frac{1}{2Ka} \left[ A_0 + \sum_1^{n=\infty} na p_1 A_n \operatorname{csc}(na p_1) \cos(n p_1 x + \theta_n) \right] \quad (39)$$

If  $F(x)$  is obtained as a power series in  $x$ , it is advantageous to expand equation 38 in a power series in  $p$  and then apply it to  $F(x)$  term by term as in equation 36. When this is done there results<sup>12</sup>

$$f(x) = \frac{F(x)}{2Ka} + \frac{1}{K} \sum_1^{n=\infty} \frac{(-1)^n (2^n - 1) B_n a^{2n-1}}{|2n|} \frac{d^{2n} F(x)}{dx^{2n}} \quad (40)$$

where  $B_n$  are the Bernoulli Numbers  $1/6, 1/30, 1/42, \text{etc.}$

When equation 40 does not terminate finitely, its convergence must be investigated. A solution for  $f(x)$  when  $F(x)$  is of the third degree has been determined, and is

$$f(x) = \frac{1}{2Ka} \left[ (F_0 - a^2 F_2/3) + (F_1 - a^2 F_3)x + F_2 x^2 + F_3 x^3 \right] \quad (41)$$

where

$$F(x) = F_0 + F_1 x + F_2 x^2 + F_3 x^3 \quad (42)$$

Another solution for  $f(x)$  further illustrating the use of operational methods can be obtained. A partial fraction expansion for  $\operatorname{csch}(ap)$  is<sup>13</sup>

$$\operatorname{csch}(ap) = \frac{1}{ap} + 2 \sum_1^{n=\infty} \frac{ap(-1)^n}{a^2 p^2 + n^2 \pi^2} \quad (43)$$

By the use of equations 38 and 43, 37 becomes

$$f(x) = \frac{F(x)}{2a} + \frac{1}{Ka} \left[ \sum_1^{n=\infty} \frac{(-1)^n}{p^2 + n^2 \pi^2/a^2} \right] F''(x) \quad (44)$$

where  $F''(x) = \frac{d^2 F(x)}{dx^2}$ .

Application of a typical term of the indicated summation in 44 to  $F''(x)$  results in

$$\left[ \frac{1}{p^2 + n^2 \pi^2/a^2} \right] F''(x) = \frac{a}{n\pi} \int_x^\infty \sin[n\pi(x - \lambda)/a] F''(\lambda) d\lambda \quad (45)$$

where  $\lambda$  is a variable of integration.

The complete solution is finally

$$f(x) = \frac{F(x)}{2Ka} + \frac{1}{K\pi} \sum_1^{n=\infty} \frac{(-1)^n}{n} \int^x \sin [n\pi(x-\lambda)/a] F''(\lambda) d\lambda \quad (46)$$

The choice between equations 40 and 46 is dependent upon the form of  $F(x)$ .

#### EXAMPLE OF ONE-DIMENSIONAL SYNTHESIS

It is evident that in the above example, the scanned output does not bear a linear relation to the field scanned, except perhaps in certain simple fields. This is entirely due to the shape and field distribution of the scanning beam. As may be seen from equation 32, the linearity increases as the beam width is decreased, with the disadvantage of a decrease in the scanned output. It would certainly be of interest to investigate the possibilities of a beam field distribution that would introduce no distortion in the scanned output, at least up to some predetermined cut-off frequency.

The requirements are therefore,

$$T(jp_1) = \begin{cases} z, & p_1^2 < \omega \\ 0, & p_1^2 > \omega \end{cases} \quad (47)$$

where  $\omega$  is the cut-off frequency and  $z$  is constant.

Inserting the conditions of equation 47 in equation 11 gives

$$P(\alpha) = \frac{z}{2\pi} \int_{-\omega}^{+\omega} e^{-j\alpha p_1} dp_1 \quad (48)$$

Equation 48 is easily integrated, resulting finally in

$$P(\alpha) = \frac{z}{\pi\alpha} \sin(\alpha\omega) \quad (49)$$

Evidently the required scanning beam extends to plus and minus infinity. The beam intensity decreases in an oscillatory manner through positive and negative values from a maximum at the origin to zero at infinity. Such a beam is in reality not obtainable because it is impossible to secure a beam of infinite extent. The fact that the scanning beam is actually finite in width is usually the greatest limiting factor in securing any required frequency characteristic. The means for simulating negative fields in the scanning beam will not be discussed here.

Assume that the field of the beam is zero outside of  $\pm a$  and that the field is described by equation 49 within  $\pm a$ . From equation 10 the form for  $T(jp_1)$  is

$$T(jp_1) = \frac{\omega z}{\pi} \int_{-a}^{+a} \frac{\sin(\alpha\omega)}{\alpha\omega} e^{j\alpha p_1} d\alpha \quad (50)$$

Because of symmetry about the origin, equation 50 may be written

$$T(jp_1) = \frac{2z}{\pi} \int_0^a \frac{\sin(\alpha\omega) \cos(\alpha p_1)}{\alpha} d\alpha \quad (51)$$

After expanding the integrand in equation 51 into a trigonometric sum, re-writing and integrating, there results

$$T(jp_1) = \frac{z}{\pi} \left\{ Si[a(\omega + p_1)] + Si[a(\omega - p_1)] \right\} \quad (52)$$

where  $Si$  is the term for integral sine.<sup>14</sup>

A plot of equation 52 has been made in Fig. 5 in which  $a\omega$  has been taken as equal to  $2\pi$ , and  $z$  equal to unity. It is interesting to note the evidence of a definite low-pass characteristic, even for this short beam-width.

In certain applications, such as in television, it does not seem possible to simulate a scanning beam with a negative field. However, suppose another field  $P_1(\alpha)$  is added to equation 49 such that their sum is never negative, thus:

$$P(\alpha) = \frac{z}{\pi\alpha} \sin(\alpha\omega) + P_1(\alpha) \quad (53)$$

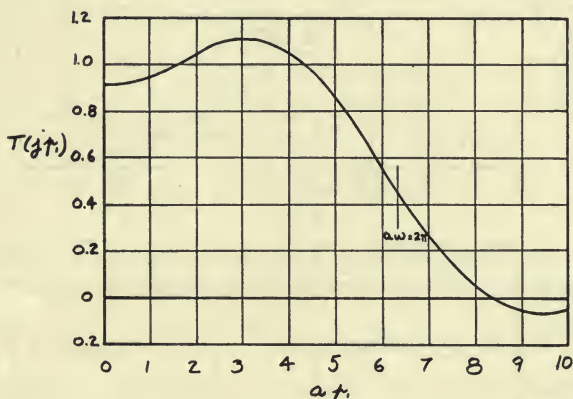


FIG. 5. Frequency characteristic, sine distribution.

For convenience, the distribution described by equation 49 could be termed a "sine distribution," and that of equation 53 a "partial sine distribution."

The form of  $P_1(\alpha)$  should be so chosen that the qualities of the sine distribution may be as closely approximated as desired. This requires the contribution of  $P_1(\alpha)$  to the scanned output to be as small as possible, at least in the region containing the frequencies of interest. These requirements are not usually easy of achievement.

As an example, the effect of adding the sine distribution to the rectangular beam will now be considered. Assume that the distribution within  $\alpha = \pm a$  is

$$P(\alpha) = \frac{\omega z}{\pi} \left[ \frac{\sin(\alpha\omega)}{\alpha\omega} + k \right] \quad (54)$$

where  $k$  is a constant such that  $P(\alpha)$  is never negative.

The largest negative value of the sine distribution occurs when  $\alpha\omega = 3\pi/2$ , thus the smallest value that  $k$  can have is  $2/(3\pi)$ . For this example it will be assumed that  $a\omega = 3\pi/2$ , and that  $k = 2/(3\pi)$ . The relative distribution is shown in

Fig. 6(a). The distribution is symmetrical about the center of the beam. In the figure, however, only the right half is shown.

When equation 54 is inserted in 10, integrated, and the assumed values inserted, there is obtained

$$T(jp_1) = \frac{2z}{\pi} \left\{ \frac{1}{2} \left[ Si(3\pi/2 + ap_1) + Si(3\pi/2 - ap_1) \right] + \frac{1}{ap_1} \sin(ap_1) \right\} \quad (55)$$

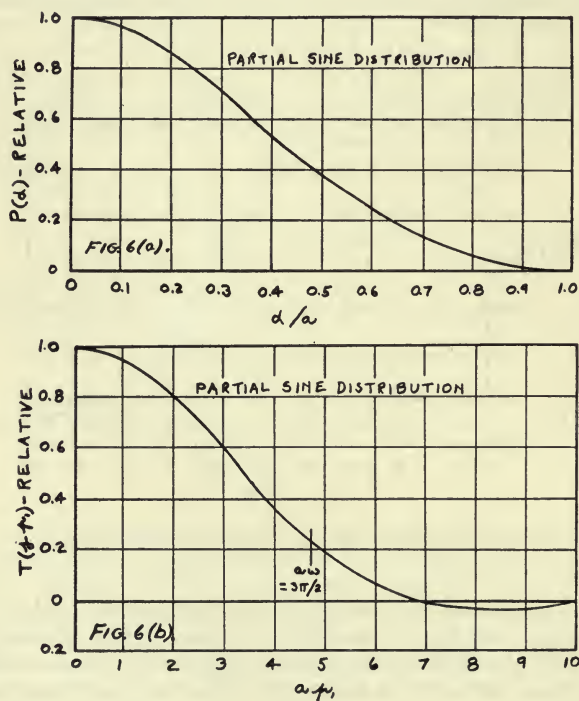


FIG. 6. Partial sine distribution.

The relative values for  $T(jp_1)$  have been plotted in Fig. 6(b). Quite evidently the low-pass characteristic has been somewhat obliterated by the addition of the rectangular beam. The accuracy of the curves is governed by tabular and slide-rule error.

In concluding this section, it must be pointed out that the examples were considered mainly as illustrations of the application of the theory. In a similar manner beam-field distributions can be devised that will yield any required frequency characteristic.



**Appendix 2****EXAMPLE OF TWO-DIMENSIONAL ANALYSIS**

A commonly used scanning spot is that generated by a cathode gun. This spot is circularly symmetrical with a radial field given by<sup>15</sup>

$$P(S) = Ve^{-a^2S^2} \quad (56)$$

where  $V$  and  $a$  are constants.

Inserting equation 56 in 20 and integrating gives the scanning operator

$$T(M) = \frac{V\pi}{a^2} e^{M^2/4a^2} \quad (57)$$

If, as is customary, the field being scanned is represented by the double Fourier series

$$f(x, y) = \sum_n \sum_m A_{nm} \cos [np_1x + mq_1y + \delta_{nm}] \quad (58)$$

and equation 57 is applied, there is obtained

$$F(x, y) = \frac{V\pi}{a^2} \sum_n \sum_m A_{nm} e^{-(n^2p_1^2 + m^2q_1^2)/4a^2} \cos [np_1x + mq_1y + \delta_{nm}] \quad (59)$$

Examination of equation 59 shows that the distortion due to scanning in this case is caused by a continuing diminution in amplitude of the higher order harmonics.

**EXAMPLE OF TWO-DIMENSIONAL SYNTHESIS**

As in Appendix 1, an examination of the possibilities of a distortionless scanning spot, at least up to some predetermined cut-off frequency, would certainly be of interest.

The requirements are

$$T(jM_1) = \begin{cases} z, & M_1 < \omega \\ 0, & M_1 > \omega \end{cases} \quad (60)$$

where  $\omega$  is the cut-off frequency and  $z$  is constant.

It must be remembered that in terms of the Fourier field components of (58),

$$M_1 = (n^2p_1^2 + m^2q_1^2)^{1/2} \quad (61)$$

The wavelength of a field component is  $2\pi/M_1$ ; thus the conditions of equation 60 restrict the spot response to components with wavelengths greater than  $2\pi/\omega$ . Putting equation 60 into 21 gives

$$P(S) = \frac{z}{2\pi} \int_0^\omega M_1 J_0(SM_1) dM_1 \quad (62)$$

Equation 62 is easily integrated, resulting in

$$P(S) = \frac{z\omega}{2\pi S} J_1(S\omega) \quad (63)$$

The required spot field extends to infinity with an intensity that decreases in an oscillatory manner through positive and negative values from a maximum at the origin to zero at infinity.

Such a condition is not exactly obtainable because in this application it does not seem possible to simulate negative spot fields. Also the spot is in reality of finite extent.

It is possible to add another field  $P_1(S)$  to equation 63 such that their sum is never negative:

$$P(S) = \frac{z\omega}{2\pi S} J_1(S\omega) + P_1(S) \quad (64)$$

Equation 63 could be termed a "Bessel distribution" and equation 64 a "partial Bessel distribution."

The frequency characteristic of the partial Bessel distribution may be found by inserting equation 64 in 21, i. e.,

$$T(jM_1) = z\omega \int_0^a J_1(S\omega) J_0(SM_1) dS + 2\pi \int_0^a SP_1(S) J_0(SM_1) dS \quad (65)$$

where  $a$  has been taken as the radial extent of the spot.

It is interesting to note that the first integral in equation 65 is a step function<sup>16</sup> such that

$$z\omega \int_0^\infty J_1(S\omega) J_0(SM_1) dS = \begin{cases} z, & 0 < M_1/\omega < 1 \\ 0, & 0 > M_1/\omega > 1 \end{cases} \quad (66)$$

No tables of equation 66 for a finite upper limit seem to be available. Rough calculations show it to be somewhat similar to the frequency characteristic of the sine distribution discussed in Appendix 1.

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## STABILITY OF SYNCHRONOUS MOTORS\*

S. READ, JR., AND E. W. KELLOGG\*\*

*Summary.*—For the most part, since the advent of talking pictures, motors have been employed whose performance is excellent. The various types of motor, however, differ widely in their ability to resist load irregularities and in their tendency to oscillate when a disturbance occurs. For the more critical applications these factors deserve careful consideration when the type or design is being selected. The principal types of synchronous motor are (1) the variable-reluctance or induced-pole motor, (2) the separately excited motor, (3) the a-c-d-c motor, (4) the hysteresis motor, (5) the low-speed multi-tooth motor (of the type used for electric clocks), (6) the polyphase, uniform-torque modification of number 5, and (7) selsyn motors.

Many of the characteristics of synchronous motors may best be understood by assuming that the polyphase winding produces a uniformly rotating magnetic field, but estimating the stiffness and stability demands a knowledge of the manner in which the a-c input varies with mechanical displacement. Generous pole-face grids are essential for stability. A-c-d-c motors have certain elements of instability as well as stabilizing factors, which are not present in straight synchronous motors. The magnitude of these effects can to some extent be controlled by the external circuit arrangements. Selsyn motors are less readily damped than regular synchronous motors, and for this reason arrangements by which the synchronous motors can be interlocked from standstill are of interest.

In the days of the silent motion picture, there was nothing critical about the speed at which the film was run. In fact, prevailing projector speeds had gradually crawled upward from 60 to 70 or 80 feet per minute and most any kind of motor that would not stall was good enough.

With the advent of sound, the adoption of a standard and rigid adherence to the same was immediately essential. Engineers promptly realized this and after a short period of question as to what the standard speed was to be, adopted 90 feet per minute as a standard and fell to work to build accurately controlled driving systems. These included governed d-c motors and motors controlled by electric governors which were highly sensitive to the frequency of a tone

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\* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received February 28, 1941.

\*\* RCA Manufacturing Co., Camden, N. J.



generated by a device attached to the motor. Where a power source of reasonably constant frequency was available, synchronous motors were used and these have been highly satisfactory. Induction motors have been widely used for machines which did not have to be synchronized with others, and where a variation of one or two per cent was not serious, provided there were no rapid changes. The average slip of an induction motor can be compensated in the gearing.

Synchronous motors for use in the motion picture industry are for the most part designed to work with polyphase alternating currents. In an appropriately designed winding, the polyphase currents result in a magnetic field of practically constant intensity, which rotates

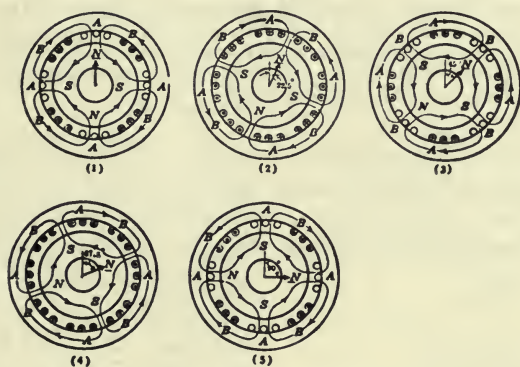


FIG. 1. Production of a rotating magnetic field by a polyphase winding.

with respect to the windings at a speed determined by the number of poles which the winding is designed to produce, and the frequency of the a-c supply. Fig. 1 shows the current distribution in a simple two-phase winding, and the resulting magnetic field at several stages of a cycle of alternation. The progressive shift of the field (which means continuous rotation) is clearly evident in the figure. The rotor is so designed that it follows this moving magnetic field, as if flexibly tied to it, but without any continuous drift behind, or slip. There are several types of synchronous motor which will be briefly described. Fig. 2 shows one of the earliest types of synchronous motor. Here the synchronous speed obviously depends on the local power plant.

*The Variable-Reluctance or Induction-Synchronous Motor.*—The type of synchronous motor which has been most widely used from the start is practically a polyphase squirrel cage induction motor, in the

rotor of which some of the teeth have been cut away or shortened to give the effect of salient poles. Fig. 3 shows the approximate rotor cross-section of such a motor. The motor is usually started by apply-

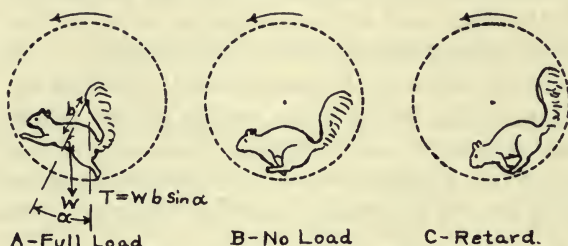


FIG. 2. Early type of synchronous motor: The reacting gravitational field rotates backward with respect to the rotor at synchronous speed but is stationary in space. The three views illustrate conditions at different stages of oscillatory cycle.

ing full voltage to the polyphase primary. It quickly comes up to nearly synchronous speed, acting entirely as an induction motor. When the speed is close enough to synchronism, the salient poles lock in with the rotating magnetic field produced by the polyphase winding and thereafter the motor continues to run in strict synchronism. Because the torque developed in a motor of this kind depends on having low magnetic reluctance in line with the field-poles and high reluctance between the poles, it is commonly called a "variable-reluctance" motor.

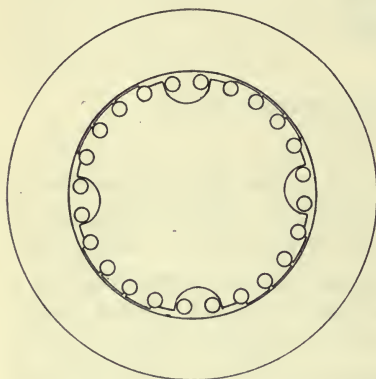


FIG. 3. Manner in which rotor teeth are cut away to produce salient-pole effect.

*Interchangeability of Rotor and Stator.*—In most designs of synchronous motors, the a-c winding may be on the stator and the field may be the rotor, or the field may be stationary and the alternating

currents supplied to the rotor through slip-rings. The principles of operation are in no wise altered by an interchange, but practical design considerations will favor or perhaps necessitate the choice of one or the other. In general, it is desirable to have the field rotate since

this calls for only two slip-rings at most, and in some constructions none at all. The stator or outside member, of course, affords more room for the windings.

*A-C-D-C Motors.*—The voltage between any two commutator bars of a d-c motor is alternating. If slip-rings are connected to suitably located taps in the armature winding, the machine becomes a rotary converter or an a-c-d-c motor. Fig. 4 shows schematically the armature of a two-pole rotary converter. The ring type of armature is used for illustration because the relation of the active (outside) conductors to the field, brushes, and slip-ring taps is most easily seen in the diagram of such a winding. The difference between the ring winding and the usual practical winding is that in the latter the conductors, instead of returning through a hole in the armature, cross it diametrically and return through the bottom of a slot under the opposite pole, thus doubling the number of effective conductors.

In a-c-d-c motors, the armature is necessarily the rotating member, with the field stationary. As applied to sound-recording work, a-c-d-c motors may be employed as straight a-c synchronous motors, or the power may be supplied from the d-c side and the a-c connections employed solely for the purpose of keeping several machines running at identical speed. Some of the well recognized characteristics of rotary converters apply to the a-c-d-c motor, but in interpreting any textbook statements about rotary converters, it should be borne in mind that in general the latter carry no mechanical load, the power intake on one side being expended almost entirely to put out electrical power on the other side. Under these conditions, the distortion of the field by the armature currents is much less than in the case where power intake may be from either or both sides and expended in overcoming mechanical loads.

*Motors with D-C Field.*—Large synchronous motors and generators always have field windings and d-c excitation. This, of course, means complication, which is particularly undesirable in small machines, the induced field or variable reluctance motor being ideal from the standpoint of simplicity. The presence of a separately excited

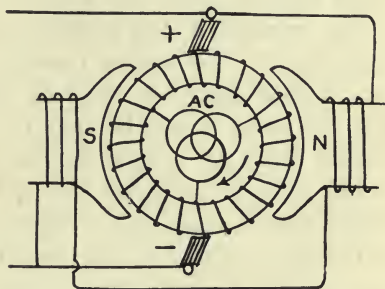


FIG. 4. Elementary type of a-c-d-c motor or rotary converter.



field reduces the a-c input requirements, largely eliminating the low power-factor demands of the motor. Other factors being equal, the addition of a field-winding around the salient poles of a field tends to stiffen the connection or make the motor drop back less in phase when a mechanical load is applied.

*Permanent-Magnet Fields.*—It might appear that since the advent of such potent materials for permanent magnets as “alnico” or similar alloys, it would be a simple matter to provide a rotating field with the required excitation by employing such magnetic material, and thereby to obtain a motor which combines the advantage of stiffness and high power-factor with the simplicity of the variable-reluctance motor which uses a soft steel rotor core. There undoubtedly are possibilities in this direction, but in ordinary service, small motors often have to stand full applied voltage when out of synchronism, as, for example, during starting, and at such times the field would be subjected to very strong demagnetizing action. This would alternate with moments of magnetic reinforcement from the a-c winding, but the result would be that the field would always be somewhat weaker than the desired normal working value, and the difference would have to be made up by lagging primary currents. These would have to make up the difference in field strength, but have to do so through a field structure comprising material which is magnetically very hard. The reduction of the required excitation which the a-c winding must supply would thus be less than might at first be expected. The foregoing applies to motors with rotating field. Permanent magnets, on the other hand, have frequently been applied to stationary fields. Here a large leakage factor can be allowed and the demagnetizing effects of the a-c winding have less effect on the permanent magnet material.

*Hysteresis Motor.*—Although there appears to be little advantage in using permanent-magnet material in a motor having a salient-pole rotor, there is a type of synchronous motor which has found many applications which employs magnetically hard material in the rotor. This is sometimes called a “hysteresis motor.” The polyphase stator produces a rotating magnetic field. The rotor is made of circular punchings of magnetically hard material, but depends on being magnetized by the stator currents rather than on a previous magnetization. If the rotor is held still while polyphase alternating current is applied to the stator, the rotor is continuously remagnetized in changing direction. The reaction of its residual magnetism with the mag-



netic field from the stator exerts a forward torque which is practically fixed in magnitude and independent of speed or slip. Such a motor gives constant torque up to actual synchronism. In other words, it can develop its full possible torque without any slip whatever, and if the load calls for less than the maximum torque which the motor can supply it will operate in strict synchronism. The constant-torque characteristic is based on the assumption that the motor is not provided with any secondary or squirrel-cage winding. If a secondary winding is provided, it will result in additional torque at all speeds below synchronism. The machine then acts as an ordinary induction motor but with the hysteresis torque added to that due to the induced currents in the secondary. In the absence of any squirrel-cage winding, the hysteresis motor is not very well damped. There is large energy loss if the oscillations are of sufficient amplitude to slip the magnetism in the rotor core but when the amplitude falls below a certain point small oscillations can persist without much damping.

In the case of motors of the salient-pole or wound-field type, there are certain positions at which the motor must lock in, and this in some applications may be of importance for maintaining accurate phase relations between several machines. If such machines, due to any temporary excess load, should break out of synchronism or slip back in phase at all, they will usually stop entirely or take such excessive current as to give an indication of something being wrong. The hysteresis motor, on the other hand, if momentarily loaded, can slip back in phase and no one be the wiser. For this reason (in part at least) it has not so far found much place in synchronous sound recording even though it is capable of carrying its normal load in perfect synchronism.

*Low-Speed Toothed-Wheel Single-Phase Motors.*—In any list of types of small synchronous motors we must include the type which has found such wide application in driving clocks. These motors consist simply in toothed wheels, outside of which are similarly toothed rings or punchings, and a winding so arranged as to produce a magnetic field between the rotor and stator. The motor runs at such speed and in such phase relation to the current, that the inner and outer teeth are opposite at the time of maximum magnetizing force or winding current. If no polarizing is provided, the rotor moves one tooth pitch in  $\frac{1}{120}$  second. These machines must be started by an impulse, which may be supplied by hand or by some auxiliary device.

*Self-Starting Toothed-Wheel Motors.*—By employing a polyphase winding or producing equivalent effect by “shading coils” the toothed-wheel, low-speed motor can be made self-starting and can be given a practically constant torque characteristic instead of jerks at  $1/20$ -second intervals. Fig. 5 shows such a motor, used in small phonographs.

*Selsyn Motors.*—A very important type of synchronous motor is the “selsyn.” It is essentially an induction motor with wound secondary instead of squirrel-cage construction, and requires slip-ring connections to the rotor. It is necessary that either the primary or secondary shall be polyphase, and for best operation both are polyphase. In operation, polyphase alternating current is applied to

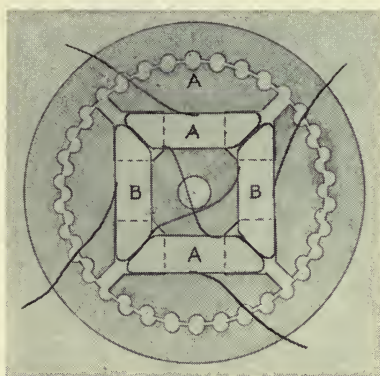


FIG. 5. Polyphase low-speed synchronous motor.

either the rotor or stator windings of a number of machines, the other windings of the motors being in parallel but not connected to any source of power. So far as principle of operation goes, it makes no difference whether the power is applied to the rotor or to the stator windings, but in discussing the machines it will be convenient to assume that the primary windings are the stators. When the voltage is applied to the stators (the rotors being connected together) the latter will undergo slight rotations and will seek such relative positions that very little current circulates. The machines in this condition act like a group of transformers paralleled on both the primary and secondary sides, but with no load on the secondary side. If the rotor of any machine is moved in either direction, the balance is upset, and cross-currents flow in such direction that they pull back on the advanced rotor and pull forward on the other rotors. If the rotors are free to turn, the entire group act as if geared together. Driving any one of the machines will cause all the others to run at exactly the same speed. Obviously, if one machine is to control a number of others, it should be larger than the ones which it controls. In sound-picture work, selsyn motors are used where it is important to lock a number of machines together before any are started, and to start and stop the entire group without any changes in relative posi-

tion, or, in other words, to make all the machines concerned feed the identical footage of film, including that which passes during the periods of acceleration and stopping. This is especially important in re-recording work where a number of reproducing machines are employed to supply sounds which are to be mixed together.

*Elementary Theory of the Synchronous Motor.*—Many of the characteristics of synchronous motors can be interpreted and understood best by making the simple assumption that the polyphase winding to which alternating current is supplied produces, relative to the winding, a magnetic field which rotates in space. This was illustrated in Fig. 1. By suitable distribution of the windings in the slots, the condition of uniform field rotating with uniform velocity can be closely approximated. If a suitably shaped piece of iron is placed within the rotor, it will obviously attempt to follow the magnetic field around. The iron armature becomes itself a magnet and its reaction with an external field is such that it tries to line up with the field. If the rotor is otherwise magnetized, the same thing occurs, but the rotor now becomes more particular about which of its poles shall be under which magnetic pole of the stator. The speed at which the stator field rotates is determined entirely by the winding and the frequency of the supply. If the winding is such as to produce two north and two south poles within the stator and the supply is 60 cycles, the field will rotate 1800 rpm. If the voltage is applied to the stator while the rotor is stationary, or if the rotor is running at some different speed, the rotor will at each instant try to line up with whatever stator pole happens to be nearest it, and it vacillates between trying to follow the stator pole which is just leaving, and going back to meet the one which it sees coming. The former tends to pull it forward and the latter to pull it backward. The forward and backward pulls alternate with the passage of the magnetic poles, but are equal on the average and no net torque is developed. The synchronous motor so far described must, therefore, have some external means for starting, or be constructed so that it will have a forward torque at speeds below synchronism. The regular induction motor has such a forward torque and its features can readily be combined with those of the synchronous motor. Induction motors ordinarily have uniform air-gaps. A set of conductors is arranged in slots around the rotor, usually in the form of copper or aluminum bars connected to low-resistance rings at each end. This is known as the "squirrel-cage" construction. When the magnetic field from the



stator travels around the rotor, it cuts the conductors and induces currents in them (provided there is difference in speed) and these currents react with the field in a direction to resist relative motion, or, in other words, to carry the rotor around with the field. The torque so developed depends on the speed difference or "slip." When the slip is large, the induced currents are large, but alternate at a frequency comparable with that of the supply. Leakage inductance causes them to lag, with the result that they do not exert as much torque as smaller currents which are in phase with the induced voltage. As the motor speeds up and the slip becomes less, the induced voltage in the rotor bars falls, but the phase difference becomes less, with the result that the torque rises to a maximum. With still further reduction in the slip the fall in voltage and current is not compensated by higher power-factor, and the torque falls off. Although the induced voltage is low at small slip, the resulting current can still be fairly large if the resistance of the conductors is low, and there will still be good torque developed. For this reason, if the induction-motor action is required to bring a machine as nearly as possible to synchronism, the resistance of the rotor conductors must be kept very low.

Nearly everyone has watched the oscillations of a compass when the needle is first set free to line up with the earth's field. The force with which a magnet seeks to line up with the magnetic field is like that of an elastic connection. In the case of a synchronous motor, the rotor poles will line up very closely with the regions of maximum magnetic strength due to the winding currents. As load is applied to the shaft, the rotor poles drop back in position but continue to follow at full speed, although slightly behind in phase; just as the draw-bar through which a train is pulled, pulls out (against spring action) when the train starts up hill, but the cars still run at the same speed as the locomotive. If some action causes the rotor poles to assume a position ahead of the stator magnetic field, they will be pulled back toward equilibrium position. The fact that the driving force is like an elastic spring and the armature has considerable mass, means that the synchronous motor is capable of oscillation or "hunting." Fortunately, there are very effective means for damping which are applicable to most synchronous motors. The same squirrel-cage or rotor conductors provided to bring the motor up to speed serve also to damp oscillations. If the stator has been lagging behind its normal or average position, and thereby receives an excess of forward pull, the machine is accelerated and for a moment runs



above normal speed to catch up. It then has an excess of kinetic energy and over-runs until the stator is ahead of its normal position. The magnetic action then pulls it back, and it again overshoots to the lagging position. To damp the oscillation, a retarding force must be applied not at the moment of maximum forward deflection, but during the moment of overspeeding that precedes the maximum deflection, and a forward torque is needed during the part of the cycle when the rotor is dropping back in phase, rather than at the time when it is farthest behind. The induced currents in the rotor conductors resist the shifting of relative positions of the rotor poles and the magnetic field with which they are reacting. Thus if the magnetic flux tends to be dragged back and forth across the rotor poles, the induced currents in the bars of the grids resist these changes. Very powerful damping can be obtained by this expedient provided the conductors are of low enough resistance.

*Stiffness.*—The fact that the poles of the rotor and stator try to line up means that there is an elastic coupling, as already described. This would be true even though the armature currents were not affected by the applied load or the displacement from the in-line position. In practically all synchronous motors, the input current is strongly affected by a displacement in the relative armature and field positions, and the increased current if the deflection is increased is in such a direction as to resist the deflection. In other words, the fact that the current changes with deflection results in a great increase in stiffness. In order to see why and how this happens, we shall resort to vector diagrams. The method of analysis is one widely applied to large machines with d-c excitation. Most of the conclusions, however, are at least qualitatively applicable to small machines, including those of the induced-pole type.

*Calculation of Currents.*—In Fig. 6 (*a*) the vector marked  $E_i$  represents the voltage impressed across one phase of the rotor winding. The vector  $E_g$  represents the voltage induced by the conductors cutting the magnetic field.  $E_g$  in general opposes the impressed voltage  $E_i$ , the current flow being regulated by the difference between these two voltages. Hence the vectors  $E_i$  and  $E_g$  are drawn in approximately opposite directions, but they are not exactly opposite. The effect of applying a mechanical load is to make any given armature coil arrive at the middle of a field-pole slightly later than it would without the load, and therefore to make the generated voltage  $E_g$  fall back in phase. The angle of lag of  $E_g$  is designated as  $x$  in Fig. 6.

If we are given the two voltages  $E_t$  and  $E_g$  and the angle  $x$ , we can easily find their resultant, which is shown as  $E_s$  in Fig. 6. The resistance  $R$  and inductive reactance  $\omega L$  of the windings give them a certain impedance which we designate as  $Z$ , and the current  $I$  lags behind the voltage  $E_s$ , which drives it through the windings, by an angle  $p$  which depends on the ratio of inductance to resistance. Having found  $E_s$  we can therefore draw the current vector  $I$ .

The next question is how much torque does the current  $I$  produce. At any given motor speed the torque is proportional to the electrical power converted into mechanical power. This power is proportional to  $E_g I \cos y$ , in which  $y$  is the angle between  $I$  and  $E_g$ . In Fig. 6 (a)

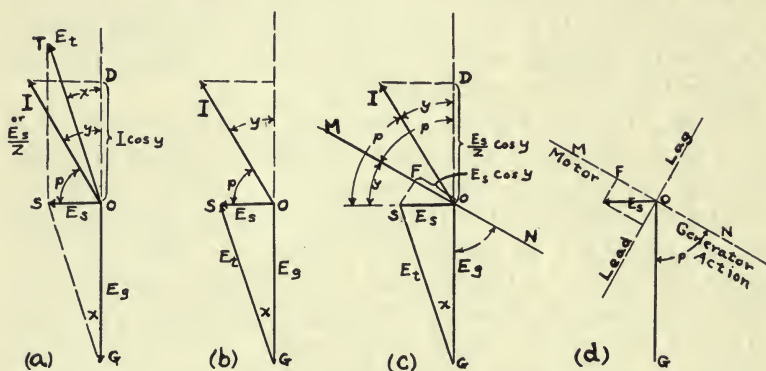


FIG. 6. Voltage and current relations in synchronous motor.

$I \cos y$  appears as the projection  $OD$  of vector  $I$  on the extension of the  $E_g$  vector.

Although the action of the machine may be analyzed by going through the steps just described, the diagram can be simplified and the effects of changing certain quantities more easily followed. In Fig. 6(a) a parallelogram is used to find the resultant  $E_s$  of  $E_g$  and  $E_t$ . Only the lower half of the parallelogram is really needed. Thus in Fig. 6(b)  $E_g$  is laid off from  $O$  as before, the line  $GS$  is drawn to represent the vector  $E_t$  and the line  $OS$  which closes the triangle is  $E_s$ . From  $E_s$ ,  $I$  and  $I \cos y$  are found as before.

If the immediate purpose of the diagrams is to study the effect of displacement  $x$  on input power, there is a further short-cut. In Fig. 6(c) a reference axis  $MN$  has been drawn, making the angle  $p$  with the axis  $OD$ . The angle  $y$  now appears between  $E_s$  and the new axis

$MN$ , and the projection of  $E_s$  on  $MN$  is  $E_s \cos y$ . For given values of  $E_g$  and  $Z$ ,  $E_s \cos y$  is proportional to torque. Therefore to study the effects of changes in displacement angle  $x$  on torque, we need only note the effect of changing  $x$  on  $E_s \cos y$ , found by projecting  $E_s$  on axis  $MN$ . Fig. 6(d) shows the quadrants in which  $E_s$  may fall and whether these represent motor action or generator action and leading or lagging armature current. The leading or lagging components of current supply no power, but act either to oppose or to reinforce the main field excitation.

With the foregoing theory as a background, let us consider the effect of displacement on power intake, first for the case of a motor having a high value of  $\omega L/R$ . Appropriate diagrams are shown in

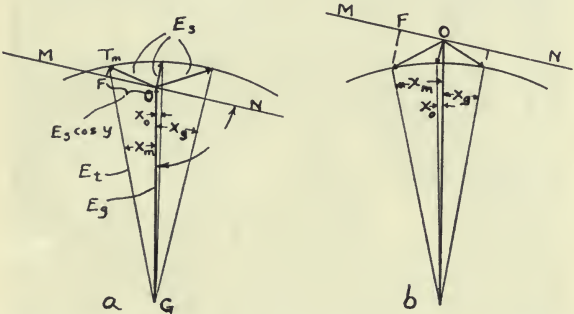


FIG. 7. Current vs. load relations in machine with high ratio of  $X/R$ .

Fig. 7, in which diagram *a* represents the conditions when  $E_g$  is less than  $E_t$ , and diagram *b* the conditions when  $E_g$  is greater than  $E_t$ . In each case three values of displacement angle  $x$  are taken,  $X_o$  being the angle which causes no power to be supplied to the machine,  $X_m$  is an angle giving motor action, and  $X_g$  an angle which causes generator action. Only one set of the vectors  $E_g$ ,  $E_t$ ,  $E_s$ , and  $E_s \cos y$  in Fig. 7(a) is labeled: namely, the one corresponding to  $X_m$ . The locus of  $E_t$  as  $x$  changes is an arc of a circle, and since the  $E_s$  vector is drawn from the end  $O$  of the  $E_g$  vector to the end  $T$  of the  $E_t$  vector, its locus is the same circle. It will be noticed that the effect of changing  $x$  is to cause a major change in  $E_s \cos y$ , for the reason that the circular arc, which is the locus of the end of the  $E_s$  vector, is nearly parallel to the axis  $MN$ . On the other hand, the component of  $E_s$  perpendicular to  $MN$  (which means lagging current in the case of



Fig. 7(a), or leading current in 7b) changes only slightly with changes in load (changes in the angle  $\alpha$ ). The rapid increase in the torque-producing component of current (proportional to  $E_s \cos y$ ) with change of displacement  $\alpha$ , means that such a motor will strongly resist a displacement, or, in other words, it will be stiff.

*Effect of Resistance on Stiffness.*—Let us next, for the sake of comparison, assume that resistance predominates over reactance in the motor-winding impedance, making the angle  $p$  small, which gives the reference axis  $MN$  a direction more nearly at right-angles to the circular arc. Vector diagrams for a somewhat exaggerated case of such a machine are illustrated in Fig. 8. We now find that a shift in the

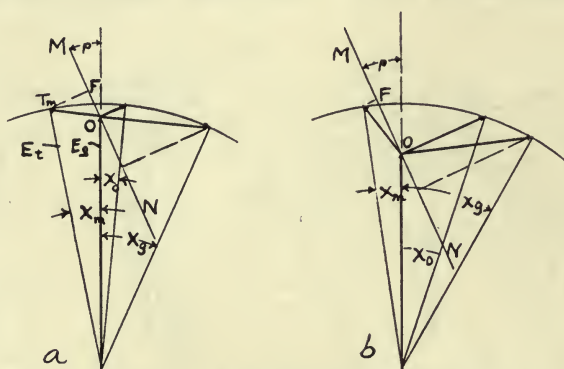


FIG. 8. Current vs. load relations in machine with low ratio of  $X/R$ .

displacement angle  $\alpha$  between  $E_g$  and  $E_t$  results principally in producing leading or lagging currents with comparatively small changes in the torque produced. Therefore, high resistance in the winding or the power-supply leads greatly reduces the stiffness of the motor. As compared with Fig. 7, the conditions of Fig. 8 (small value of  $\omega L/R$ ) result in a machine in which mechanical load produces large differences in the leading or lagging components of current, and therefore the field-strength is strongly affected by the load. It further appears from Fig. 8 that unless the generated voltage  $E_g$  is considerably less than the line voltage  $E_t$ , the machine will not be able to carry much motor load. If  $x_m$  increases, the projection  $OF$ , which represents power intake, will increase only slightly and then begin to decrease as  $T_m$  passes the tangent point. This means that the motor would fall out of step. If the generated voltage were 20 per cent



higher than shown, the machine would not be able to run at all as a motor. It should be noted also that as the load is increased (approaching the pull-out limit) the stiffness rapidly becomes poorer, and fluctuations in the leading (demagnetizing) component of armature current with changes of load (*i. e.*, changes in the length of  $FT_m$ ) are exaggerated.

In the analysis just given,  $E_g$  is based on normal field-strength excluding the effect of armature reaction on the field, but armature reaction is taken into account in the value taken for winding inductance (see Appendix). The method is not rigorously applicable to salient-

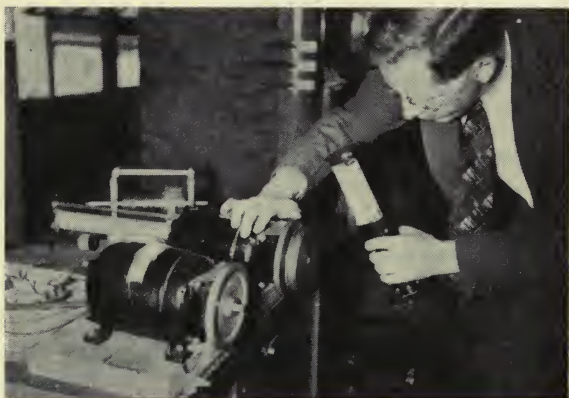


FIG. 9. Testing motors for stiffness and oscillation by means of stroboscope.

pole motors, because the armature reaction and therefore the value of  $Z$  is not the same for components of current which are in phase and those which are in quadrature with the voltage. The quadrature currents reach maximum when surrounding the main field, and in this position, the reluctance is low and a large magnetic effect is produced. The in-phase or power-carrying currents reach maximum when the coils are turned at right-angles to the field and the reluctance is maximum. Therefore, the reactance is lower for the power components of armature currents than for the magnetizing components, and this reduces, though it does not eliminate, the detrimental effects of resistance on the phase-angle of the current. An analysis which takes the difference in reluctance into account is given in an Appendix.

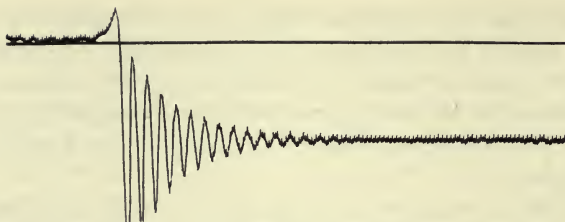


FIG. 10 (a). A-c-d-c motor, separate excitation  $I_f = 0.385$ ; no resistance in leads.

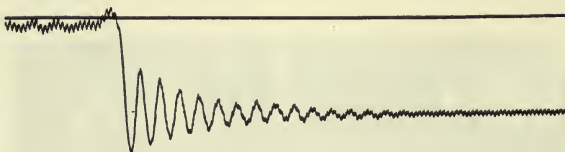


FIG. 10 (b). A-c-d-c motor, separate excitation  $I_f = 0.390$ ;  $R = 3\frac{3}{4}$  ohms in each lead.

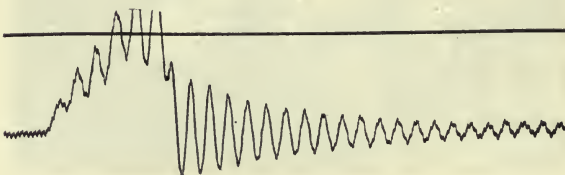


FIG. 10 (c). A-c-d-c motor, self-excited,  $I_f = 0.390$  ampere;  $R = 3\frac{3}{4}$  ohms.

The reduced stiffness resulting from inserting resistance in the leads may be observed by mounting a stroboscopic disk on the motor shaft, illuminating the disk with a flashing light-source and noting how far the armature is deflected when a small brake load is applied. Fig. 9 shows this test being made. A still more satisfactory method of studying the performance of a motor is by means of oscillograms of armature displacement, such as those shown in Figs. 10 and 11. The reduction in stiffness due to the resistances is shown by the lower frequency of the oscillations in curve *b* of Fig. 10 than in curve *a*. The tests were made on an a-c-d-c motor. The armature was deflected 5 mechanical degrees and then released. (The 5-degree deflection was reached with a much less brake torque load in some cases than in others.) When the resistances were introduced, the supply

voltage was raised to make up for the drop in the resistors. The method of making the oscillograms is of interest. The output of a magnetic tone-wheel on the shaft of the motor being tested was combined with that of a similar reference tone-wheel on another motor in such a way that rectification gave a direct current bearing a linear relation to the angle of phase displacement between the motors, and this direct current was supplied to the oscillograph galvanometer. Each oscillogram covers a period of about 4 seconds. Measurements of stiffness were also made by means of a prony brake and a stroboscope. The results are given in Table I.

TABLE I

	Tied to D-C Line?	Resistors in Three-Phase A-C Leads	Voltage at Slip Rings	Excitation	$I_f$	Stiffness in Oz-In per Degree	
						No Load	At 75 Oz-In
A	No	None	68.5	None	0.000	15.0	11.5
B	No	None	68.5	Self	0.390	26.0	22.0
C	No	$3\frac{3}{4}$ ohm	69	None	0.000	12.6	8.3
D	No	$3\frac{3}{4}$ ohm	73	Self	0.390	15.4	14.8
E	No	None	68.5	Separate	0.390	24.0	20.6
F	No	$3\frac{3}{4}$ ohm	73	Separate	0.390	14.6	12.0
G	Yes*	$3\frac{3}{4}$ ohm	73	Separate	0.390	20.0	22.4
H	Yes*	None	68.5	Separate	0.390	27.0	26.4

\* D-c line voltage equal to motor brush voltage before connecting.

*Effect of Field Excitation on Stiffness.*—It is of interest to compare the stiffness of a motor provided with d-c excitation with a salient-pole motor depending entirely on the a-c winding to supply the excitation. Obviously, the stiffness of the latter depends on how much the reluctance is increased between poles, or, in other words, on how much of the field structure is cut away. With a d-c field winding, on the other hand, a substantial stiffness can be had with a uniform air-gap. The only condition, therefore, in which the two types of motor would be comparable is that in which the reluctance between poles is so high and the flux in this region so weak that it exerts little force. If the resistance and leakage reactance of the armature windings are small, the total field flux linking the armature turns will be nearly the same in two motors of similar proportions and a-c winding design, one of which has d-c excitation, while the other depends on the a-c winding to produce the field. Those who have wrestled with transformer theory will recall that the general design formulas assume a definite

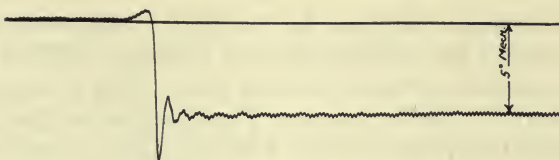
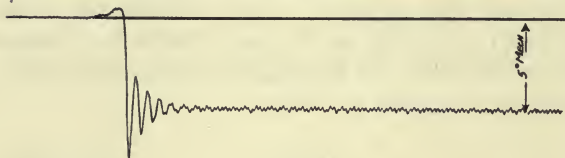
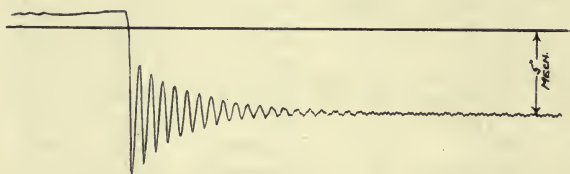


FIG. 11 (a). A-c-d-c motor, field winding shorted.

FIG. 11 (b). A-c-d-c motor, self-excited,  $I_f = 0.29$  ampere, 1800 rpm.FIG. 11 (c). A-c-d-c motor, self-excited,  $I_f = 0.385$  ampere.

relation between the applied voltage, the number of turns, and the maximum magnetic flux. A similar relation holds in the case of the synchronous motor. The total amount of flux which a given winding must interlink in order to develop a counter-electromotive force substantially equal to the impressed voltage is determined by the number of turns in the winding. The general conclusion is that if a separate winding does not supply the necessary field, then the a-c winding will do so. It accomplishes this, of course, by drawing a strong lagging current, and while this, in certain applications, may be considered a drawback, it does not seriously prejudice the operation of the motor, provided the winding is of low resistance.

The principal difference between the stiffness of a motor with field excitation, and one with similar field structure, but depending on the a-c winding to provide excitation, is that the force reaction between the magnetizing component of current and the cross-field is opposite in sign to the reaction between the power component of current and the main field. Therefore eliminating the magnetizing current re-



moves this subtractive factor. Another way of describing the same effect is to say that with d-c excitation the resultant field does not shift in position with changing load as much as it does in the case of the induced-pole motor. If a given motor is tested (as illustrated in Table I) with and without field excitation, there is further loss of stiffness for the case of a-c excitation, due to the a-c winding impedance and consequent somewhat reduced field-strength. On the other hand, since iron losses and saturation are the factors which set the flux limits, it is logical to design a simple variable-reluctance motor to operate with about the same flux density as a d-c excited motor of like proportions. Thus in comparing types of motors, the field-strength factor should not be counted, but in the case of small motors a difference in stiffness may be expected of the order of 1.5 to 1 in favor of the motor with d-c field, due to the fact that the field does not shift as much with changes of load. How much this difference amounts to depends largely on the ratio of reluctance in line with and at right-angles to the main field-poles.

Fig. 11 shows the effect of suddenly removing a brake load from the a-c-d-c or "interlock" motor with which the tests of Fig. 10 were made. It is seen that the natural period (which is determined by the stiffness) is only slightly altered by excitation. On the other hand, the tendency to oscillate increases decidedly with field current. The same is true when the field is excited from a separate source.

The better damping when the motor is operated without field excitation is explained in part by the greater field-shift or cross-magnetization for a given load. This results in a greater resistance effect relative to the stiffness, the resistance effect being largely due to the currents induced in the damping windings. There are other factors which give an advantage on the score of damping to the motor which has no field excitation. Most of the writers cited in the bibliography show both by theory and by test that stability is best at low excitation, that resistance is prejudicial, and that heavy motor loads aggravate the tendency to oscillate.

*Positive and Negative Damping Factors.*—As may be seen from the diagrams of Figs. 7 and 8, an increase in generated voltage (at a given value of displacement angle) has the effect of decreasing the electrical power intake as a motor or of increasing the power output as a generator, or, in either case, to cause mechanical retardation. Conversely, a reduction in generated voltage favors motor action or discourages generator action, and thus helps forward motion. This

is true whether the machine has a large or a small ratio of  $\omega L/R$ , but the effect is more pronounced in the latter case.

Changes in generated voltage may result from either changes in speed or changes in field strength. Those due to speed result in damping of oscillations, since they cause a retarding torque during moments of over-speed and a forward torque during the part of the oscillation cycle when the rotor is falling behind in position. Further damping is provided by the effect of pole-face grids or damping windings which absorb energy whenever the cross-field changes in strength or direction.

An oscillation is accompanied by periodic weakening and strengthening of the field. As was pointed out in discussing Fig. 8, a backward displacement of the rotor causes increased power intake (and this provides stiffness, which is desirable) and it also causes a demagnetizing component of current to flow, while a forward displacement results in a magnetizing current. The fluctuations in field-strength that these magnetizing and demagnetizing currents produce would only help to increase the stiffness of the machine, were they exactly in phase with the forward and backward displacements; but because of its stored energy the field-strength actually lags considerably behind the factors tending to strengthen or weaken it. As a result of the lag, the field is weakest just *after* the greatest backward deflection, and strongest just *after* the greatest forward deflection. Remembering that a reduction in field-strength tends to cause motor action or forward torque while an increase in field-strength results in generator action and a backward torque, we see that the fluctuations in torque are so timed as to supply energy to the oscillations, or to produce what might be called "negative damping."

A small armature phase-angle (angle  $p$  of Fig. 6, corresponding to a small ratio of reactance to resistance) tends to magnify this negative damping for two reasons: (1) it increases the magnetizing and demagnetizing currents which result from a given deflection, and (2) it makes the power intake more sensitive to the magnitude of the generated voltage. The second of these factors applies also to the positive damping which results from the changes in generated voltage with changes of speed, but the slight benefit which may result from increasing the positive damping by resistance is much more than offset by the increase in negative damping. Both the positive and the negative damping also depend on persistence of field-strength, but in different degrees.

Quantitative analyses of the actions that take place when a synchronous machine hunts lead to rather complicated formulas, and bring out some factors besides the ones enumerated above, but related to them, and likewise dependent on the tendency of the field magnetism to change only slowly. Some further discussion will be found in the Appendix. The negative damping is by no means a theoretical factor of minor importance, but may, unless motors are well designed and used in the best way, cause serious trouble, and in any case causes impairment of the steadiness of the motor.

*A-C-D-C Motors.*—Motors of this class are essentially the same as rotary converters. In some machines, the d-c and a-c windings are separate, but wound in the same slots. This does not materially alter the general characteristics of the machine and we shall consider the single-winding type of machine.

Since an a-c-d-c machine or rotary converter necessarily has a rotating armature and stationary field, and it also has a ready source of direct current for exciting the field, all machines of this type are of the d-c field type. Placing the a-c winding on the rotor instead of on the stator means some sacrifice of available winding space. The machine may therefore be expected to have a somewhat higher resistance than a motor of the variable-reluctance type of comparable rating, and this is a disadvantage, but the disadvantage (so far as efficiency is concerned) is in part offset by the higher power-factor and consequent reduced winding current which a d-c field makes possible. In the matter of maximum or pull-out torque, the machine with d-c field not only has greater stiffness, but can be displaced farther before it reaches the point of maximum torque.

Since the earliest days of parallel operation of synchronous machines, rotary converters have been more prone to cause trouble from hunting than simple synchronous motors and generators. Note, for example, the following quotation from *Electrical Machinery*, by Dawes (McGraw-Hill, 1922; 11, p. 374):

"The converter is very sensitive to line disturbances such as fluctuations of voltage or frequency. Accordingly it has a much greater tendency to 'hunt' than has the synchronous motor."

The fact that power can be supplied to and given out from a rotary converter through either the a-c or d-c connections makes it necessary to control several factors which cause no trouble in simple synchronous motors and generators. Thus, it is quite easy to cause a machine to take in power from the d-c side and feed power back into



the a-c line while other machines with which the first is in parallel are doing the reverse. If the armature and d-c supply are of low resistance, the d-c power intake is sensitive to excitation or generated voltage, since (unlike a d-c shunt motor) it can not change speed to compensate for a change of field-strength. In any rotary converter (and to some extent in machines with double windings) the a-c and d-c voltages bear an almost fixed relationship.

From the standpoint of armature oscillations, the same factors which produce both positive and negative damping in simple synchronous motors are exaggerated in the case of a rotary converter or a-c-d-c motor, for the reason that in addition to the changes in power intake from the a-c side there is the additional and far more sensitive source of power flow through the d-c terminals. The direct current which flows through the armature is equal to the difference between the voltage applied to the brushes and the counter-electromotive force, or generated voltage, divided by the armature resistance. This voltage difference (in an efficient machine) is quite small in comparison with the applied and generated voltages themselves. In other words, a rather sensitive balance determines the power intake. In tests of the small a-c-d-c laboratory motor previously mentioned, connecting the brushes to a constant-voltage d-c supply increased the positive damping more than it did the negative damping, making the machine more stable and also stiffer. This was true provided the d-c line voltage was equal to or higher than the brush voltage before closing the switch. Material induction of the d-c line-voltage made the machine unstable. Low d-c line-voltage makes the machine put out d-c power and take in a-c power. It has already been pointed out that stability becomes poorer with high motor load. The fact that stability was critical to this voltage relation is an illustration of the fact that a-c-d-c motors require more careful control of operating conditions than simple a-c motors.

If an a-c-d-c machine is operated from the a-c side alone, but its field is excited from its own d-c brush voltage, there is a cumulative effect of armature reaction. Thus when the armature reaction weakens the field, the d-c voltage falls and this in turn reduces the d-c excitation. In this case, the time lag between the field-strength and the armature reaction which originally caused it is increased, and the magnitude of the field-strength fluctuation is also increased, with the result that the negative damping or the tendency to oscillate is aggravated. The magnitude of the effect just described would be ex-



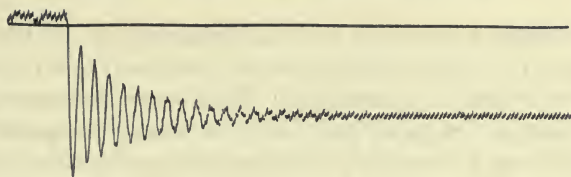


FIG. 12 (a). A-c-d-c motor; no d-c connection  $E_{ring} = 69$  separately excited  $I_f = 0.390$ ; no resistance in a-c leads.

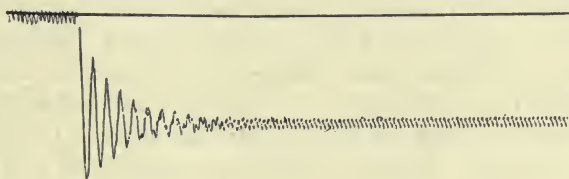


FIG. 12 (b). A-c-d-c motor tied to 103-v d-c  $E_{ring} = 69$   $I_f = 0.390$ ; no resistance in a-c leads.

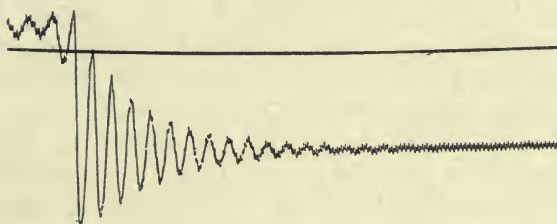


FIG. 12 (c). A-c-d-c motor—not tied to d-c  $E_{ring} = 78$  separately excited  $I_f = 0.390$ ,  $R = 3\frac{3}{4}$  ohms.

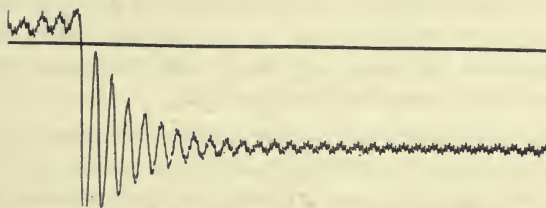


FIG. 12 (d). A-c-d-c motor, tied to 117-v d-c  $E_{ring} = 78$ ,  $I_f = 0.390$ ,  $R = 3\frac{3}{4}$  ohms in a-c leads.

pected to depend upon the natural frequency of the motor as determined by the motor stiffness and the total inertia of the motor and the load to which it is connected. With very little inertia, the oscillation may be so rapid that the field-strength scarcely changes, while with very low natural frequency the angle of lag of the field-flux behind the armature reaction becomes small. Between these extremes, the tendency to hunt is worst.

Comparison of the oscillations in Figs. 10(a) and 11(c) shows that with no series resistance in the a-c leads, separate excitation (10a) gives slightly better damping than self-excitation, but the difference is not great. On the other hand, with  $3\frac{3}{4}$  ohms connected in series with each of the three-phase leads, self-excitation (10c) gave bad results. With the combination of resistances and self-excitation, the motor would not carry the load (brake load required to give 5-degree average deflection) without continuous oscillations, and when the load was thrown off, the oscillations persisted for a long time.

The oscillograms of Fig. 12 show that in the case of the machine used for our tests, connecting the brushes to a constant-voltage d-c supply increased both stiffness and damping, and this was true with, as well as without, resistors in the a-c leads. Operating with the brushes connected to a constant-voltage d-c supply of course eliminates fluctuations in the voltage applied to the field winding and is thus equivalent to providing separate excitation, in addition to affording a path for power-supply to or from the armature. When a-c-d-c machines are driven from the a-c side only, they would normally be self-excited and this has been seen to be inferior to separate excitation.

Table I shows the effects of various operating conditions on the stiffness (or load vs. deflection) of the small a-c-d-c motor. When resistances were connected in the leads, the supply was shifted to the next higher voltage taps on a three-phase transformer. This slightly more than made up for the drop in the resistors. Had the slip-ring voltages been kept the same, the loss of stiffness due to the extra resistance would have been more pronounced.

The results of our tests may be summarized as follows:

- (1) The resistance of windings and of the a-c supply lines should be kept as low as possible, both for the sake of stability and stiffness.
- (2) Damping is improved as field current is reduced and is best when the excitation is supplied by the a-c windings alone. The im-

proved damping is at the cost of some (though not serious) loss of stiffness.

(3) If the machine has a field winding but no d-c is supplied, short-circuiting the field winding has practically no effect on damping, but the short-circuiting of the field does help greatly toward bringing the machine up to speed as an induction motor. If direct current is supplied to the field, the damping is not noticeably affected by increasing the resistance in series with the field (the supply voltage being increased at the same time to keep the field current the same).

(4) Self-excitation gives approximately the same stiffness as separate excitation, but decidedly more tendency to oscillate, especially if the resistance for alternating current is large. Hence the method of operation in which an a-c-d-c motor is run from an a-c supply alone, but supplies its field current from its own brushes, is not to be recommended. It is better for such service to short-circuit the field winding and operate as a simple variable-reluctance motor.

(5) Connecting an a-c-d-c motor to a source of constant d-c voltage in general improves its damping and slightly increases its stiffness, provided the d-c line voltage is high enough relative to the a-c voltage to supply power to the motor rather than take power from it. The machine is quite sensitive to this voltage relation, especially if there is considerable resistance for alternating current. If the ratio of d-c to a-c voltage is satisfactory, field current has little effect on power division, and the machine can be run at low or even zero field current, and the damping thereby improved. Unfortunately, as a-c-d-c motors are generally used, the weak field operation is not practicable, for the speed of a whole group of motors is controlled by adjustments of the brush and field voltages.

With a master motor of adequate capacity and stabilized speed, the individual a-c-d-c motors, operating cameras, recorders, *etc.*, can be operated with weak fields, with advantage to their stability and ability to carry momentary or unanticipated large mechanical loads.

Some ballast resistance in the d-c lines (but minimum resistance in the a-c lines) is worth consideration when laying out a system for the synchronous operation of a number of a-c-d-c motors from a d-c supply. Each motor should have its own resistor between armature and line, preferably approximately adjusted to the mechanical load the motor will have to carry. Such a system (although sacrificing the slight gain in stiffness which a low-resistance d-c bus can give)



affords insurance against circulation of power between motors and the danger of instability which such circulation may cause.

*Selsyn Motors.*—The general construction of a selsyn motor has already been mentioned. The simple concept of a polyphase winding producing a uniformly rotating magnetic field will suffice for an understanding of most of what takes place. Let us, for example, assume that a group of motors (including one master selsyn or generator) have four-pole, polyphase stator windings supplied with 60-cycle power, the rotors of these machines being likewise wound for four poles, and that the rotors or secondary windings are connected together in parallel. At standstill, 60-cycle voltage will be developed in the secondaries, but the rotors of the machines will seek such positions that there is little interchange of current between them. When the master machine is started up, cross-currents flow which cause power to be supplied to the other machines, whose armatures throughout the period of acceleration still seek the relative positions which give minimum cross-current. When the master machine reaches 1200 rpm, the secondary frequency will have dropped to 20 cycles. The rotor currents, which flow as a result of phase unbalance between voltages induced in its secondary winding and that of the master, produce a magnetic field which rotates at 600 rpm with respect to the rotor, which is itself rotating at 1200 rpm. Thus both the rotor and stator fields are running forward together at 1800 rpm and are continuously interlocked. A selsyn motor may be thought of as a slipping clutch between the load and an over-running power source (namely, the 1800-rpm primary field). The slip is fixed by the speed of the master. To supply more power to the load, such a clutch would be tightened which would also increase the power used up in friction. Similarly, when a selsyn motor is mechanically loaded its shaft puts out mechanical power and its secondary windings put out electrical power, which power is absorbed in the master. If the master or distributor receives power from the loaded motor, why does its driving motor have to work harder at the same time? The answer is that when the selsyn motor is loaded, the 60-cycle power supplied to its primary windings goes up and that supplied to the primary of the master goes down. In a zero-loss system, if the motor supplies a torque  $T$  to a mechanical load, the 60-cycle input to the motor primary would be  $1800 T$ , the 20-cycle secondary output from the motor would be  $600 T$ , the mechanical power supplied by the motor to its load would be  $1200 T$ , the distributor driving motor would supply



mechanical power 1200  $T$ , the distributor secondary would take in 20-cycle power of 600  $T$  and the distributor primary would feed back into the 60-cycle mains 1800  $T$ . The chief matter of interest in the foregoing is that the voltage, current, and field-flux relations in the secondary windings of a selsyn motor are those of a 20-cycle synchronous generator rather than a motor, while on the primary side the relations are essentially those of an 1800-rpm synchronous motor. The field-strength is largely determined by the primary voltage.

In the case of a simple synchronous motor, the magnetic field due to the polyphase winding remains fixed in relation to the field-poles. Under these conditions, damping windings of generous design can be placed in the pole-faces and they will carry current only in case of oscillations or at moments of sudden change in phase position. In the case of the selsyn motor, this expedient is obviously out of the question. The currents induced in the pole-face grids of an ordinary synchronous motor are of the same frequency as the oscillation itself, which is quite low. On the other hand, the effect of an oscillation of a selsyn motor is to change the frequency of the secondary currents as the armature speed rises and falls. (The frequency variations last only long enough to cause a moderately small shift of phase, but a better conception of some of the effect is to be had by thinking of the variable as frequency rather than as phase.) The generated voltage in the secondary windings also rises and falls in the same ratio as the momentary value of frequency. If we assume that the impedance of the "distributor," in parallel with the other motors, is low in comparison with that of the secondary winding of the motor under consideration, and that the steady 20-cycle voltage is balanced against the voltages generated in the other machines, then any differentials in either the magnitude or phase of the generated voltage, due to oscillations, will be effective toward sending current through the windings.\* The principal reason that these differential currents would be less effective for damping than the currents in the pole-face grids of a synchronous motor, is that the latter, being of very low frequency, are substantially in phase with the voltage, whereas with

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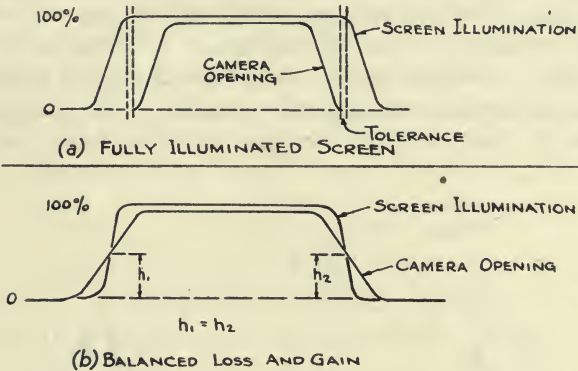
\* A simpler case wherein the same line of reasoning applies is that of a d-c generator charging a battery. In this case, with a given field-strength the mechanical resistance, expressed as torque increment per speed increment (which, if the system were an oscillatory one, would be its damping resistance), is the same when the generator is developing full voltage and charging a battery, as it would be at low speed and with the armature short circuited.

selsyn operation, the phase-angle would be that corresponding to the relation of the winding reactance to the winding resistance at 20 cycles. This phase-difference between the voltage and the current which it causes to flow, puts the selsyn motor at a disadvantage on the score of damping, as compared with a synchronous motor. As would be expected from the foregoing theory, tests show that selsyn motors are better damped (although they are less stiff) if operated at small slip than at high slip. In order to improve the damping of selsyn motors, mechanical dampers have in many cases been applied—devices, for example, resembling the rotary stabilizer used on RCA sound-heads. Some damping is also afforded if the master selsyn is driven by a motor which itself is well damped, or if the loads driven by any of the motors give mechanical damping, or if an ordinary induction motor is connected to the secondary buses.

Connecting a resistance load across the secondary windings of selsyn motors causes them to develop torque as induction motors and this expedient is sometimes used to reduce the load on the master machine. This affects damping in about the same degree that it affects the impedance of the secondary system. If resistance is low enough to result in considerable motor torque, it will probably appreciably improve damping. There does not appear to be any very satisfactory way of apportioning the resistance load between several selsyn motors, so that it will give most help to the motors which are carrying the heaviest mechanical load. In fact the resistance loading increases the danger that one of the more lightly loaded selsyn motors may break out of synchronism and run away. If any disturbance causes a selsyn motor to fall out of step, the torque developed in it alternates in direction in the same manner as that in an ordinary synchronous machine when out of step, and the interlock between the machines is entirely lost. As soon as the voltages developed in the other machines cease to bear a fixed (and continuously opposing) relation to the voltage induced in the secondary windings of the out-of-step machine, this voltage can cause a component of current in phase with itself regardless of the frequency of the other voltages in the system, and this component of secondary current gives forward torque by induction-motor action. Thus, if one or more motors in a 1200-rpm system break out of step, they tend to speed up to approach the 1800-rpm speed of their primary fields.

One of the most critical applications of synchronous motors, calling for maximum of stiffness, as well as damping, is the driving of a camera and projector in background projection work. Here any

shift in phase-angle may result in a difference in exposure, with the result that hunting shows up as a low-frequency flicker in the final picture. By special design of the shutters used in the camera and projector, it is possible to make this application far less critical than is the case with shutters of ordinary design. If the projector pull-down time can be made substantially shorter than that of the



FIGS. 13 (a) and (b). Conditions for minimizing flicker. Effect of shutter proportions and danger of flicker in background projections.

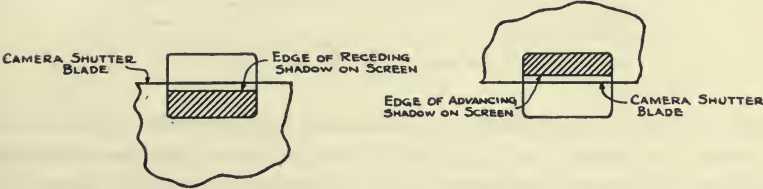


FIG. 13 (c). Conditions with focal-plane shutters.

camera, it should be possible to have the screen fully illuminated before the camera shutter begins to open, and not begin to cut off the projector light until the camera shutter is closed. The relationship is shown in Fig. 13(a). Alternatively, it is possible, as shown in Fig. 13(b), so to regulate the shutter openings that a slight gain at the beginning of an exposure is compensated by a substantially equal loss at the end, or *vice versa*. Fig. 13(c) shows the relation illustrated in Fig. 13(a), as applied to a focal-plane shutter. Rather than resort to such measures as these, however, the industry has apparently preferred to wrestle with the driving system and minimize the dis-



turbances by improving the drive. To this end, it would appear to the writers that a substitute for the present type of selsyn drive system would be decidedly advantageous for this application.

Observations of the action of selsyn motors by means of a stroboscope confirm the theory in regard to their inferior damping as compared with synchronous motors of the usual type. It is a simple matter, however, to combine the advantages of selsyn operation. (*i. e.*, complete interlock from standstill) with the superior steadiness of the synchronous motor when full speed is reached. All that is necessary is to substitute direct current (from a low-voltage source) for the alternating current normally supplied to the primary windings. This is done quickly after the machines have reached full

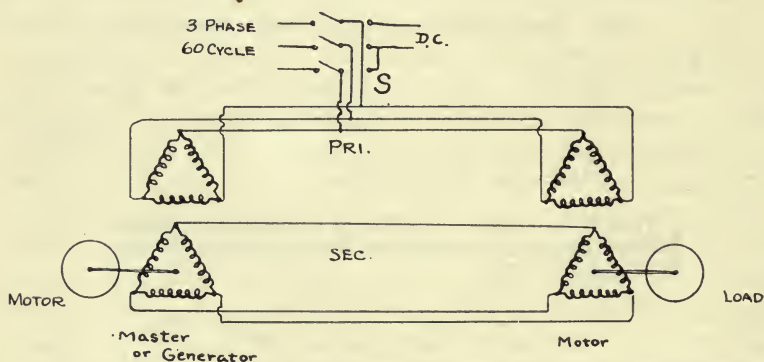


FIG. 14. Arrangement for operating selsyns as synchronous motors.

speed. Fig. 14 shows such a switch-over arrangement, applied to a generator or master and a motor. The machines are interlocked at standstill and during acceleration by polyphase 60-cycle voltage, in the usual manner for selsyn operation. As soon as full speed is reached, the switch *S* is thrown to the d-c supply, whereupon the master selsyn becomes a 40-cycle generator and the motor becomes a simple 40-cycle synchronous motor. There may be a slight phase-shift when the change is made, but not enough to make a serious disturbance, and it is readily possible independently to adjust the direct current to the generator and motors and maintain exactly the same phase relations as before switching, or to readjust mechanical phase relations while running, if desired. The polyphase terminals between which no direct current is flowing are short-circuited at the time of switching, and the short-circuited windings act as dampers.



Fig. 15 shows the improvement in damping obtained by this mode of operation. It should be noted, however, that the selsyn motor, whichever way it is operated, is not as stiff as salient-pole motors of comparable size.

*Complete Interlock of Simple Synchronous Motors.*—For complete interlock from standstill, it is not necessary to use selsyn motors. Fig. 16 shows an arrangement by which a number of synchronous motors (of the variable-reluctance type, for example) may be locked together at standstill by direct current and accelerated to full speed in complete synchronism. A commutator with bars connected to several slip-rings, is mounted on the shaft of a polyphase alternator.

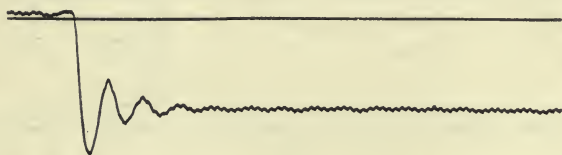


FIG. 15 (a). Selsyn motor, normal operation, 1200 rpm.

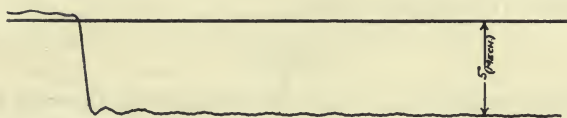


FIG. 15 (b). Selsyn motor, 40-cycle synchronous operation, 1200 rpm.

The slip-ring brushes are connected to several taps of a source of low d-c voltage, shown in the figure as a battery.

The action of the commutator is to produce a polyphase voltage whose magnitude is substantially independent of speed, and which is thus effective beginning at zero frequency. By the time inductive reactance and counter-electromotive force begin to be factors in the motor impedances, the generator windings produce enough voltage to maintain the motors in synchronism with plenty of lock-in torque. As soon as a suitable speed is attained, the commutator is taken out of circuit by a switch *S*, shown in the figure. When full speed is reached, the power-supply may be switched to the city mains, since this source would ordinarily be better than a motor-generator set, from the standpoint of constant frequency. Tests have shown this system to be entirely practicable. It offers the advantage of using

the simplest and steadiest of the various types of synchronous motor. Fig. 17 shows the complete absence of oscillation following a sudden change of load, of a  $\frac{1}{6}$ -hp variable-reluctance motor. The superior steadiness of the variable-reluctance motor as compared with a selsyn

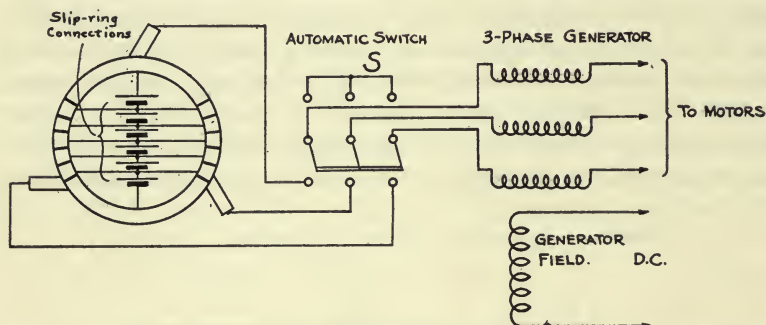


FIG. 16. Power-supply for operating synchronous motors in complete interlock.

motor (such as now used for background projection) is shown by comparing Fig. 17 with Fig. 15(a).

#### APPENDIX

*Synchronous Impedance.*—If the flow of current through a coil sets up magnetic flux, interlinking with the turns of the coil, the coil has “inductance,” and a voltage equal to  $-L(di/dt)$  is induced in the coil whenever the current changes. This relation holds whether the coil

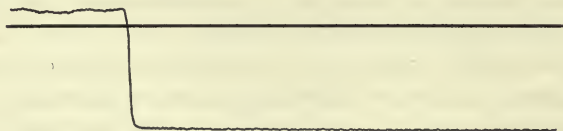


FIG. 17. Variable-reluctance motor  $\frac{1}{6}$ -hp, 1800 rpm.

is stationary or moving. If the coil is one of a polyphase winding, and is rotating synchronously, the magnetic field may be stationary in space, although alternating with respect to the individual coil. The fact that the field occupies a constant position in space means that it will not be neutralized or materially modified by induced currents in stationary coils or conductors which surround it (except for transients). Likewise if there are stationary ferromagnetic struc-

tures in the vicinity, the magnitude of the flux (for a given current in the rotating coils) may be quite different from what it would be were the magnetic field not stationary. Hence, the coils of synchronous machines show a value of inductance which is applicable only to this special case of synchronous rotation. The terms "synchronous reactance" and "synchronous impedance" have been used to describe this effect. If other windings contribute to the production of a magnetic field, the resulting voltage would obviously not be a part of the voltage of self-induction.

In addition to the magnetic field which causes the synchronous reactance, there is a local flux across the armature slots, which is not dependent on armature position, and which is responsible for a part of the reactance generally called "leakage reactance." For most purposes it is unnecessary to separate the two types of reactance (particularly since the leakage reactance is relatively small), but in considering transient effects there is an important difference in their behavior. The magnetism which passes around through the field structure represents a relatively large amount of stored energy which resists rapid change, and tends to hold the rms alternating current constant in very much the same way that inductance tends to hold the direct-current constant in a coil surrounding the flux path.

*Theory Taking Account of Unequal Reluctances.*—If it is assumed that the armature has a polyphase winding and that the conductors of each phase winding are so distributed as to produce a substantially sinusoidal distribution of magnetic potential, then the manner of variation of reluctance around the armature need not be exactly known, provided the total interlinkage (for a given current) in line with and at 90 electrical degrees to the field-poles is known. If an unexcited motor is run just under synchronous speed, the current will pass through maxima and minima, as the rotor passes through the various phase positions relative to the no load running position. The maximum synchronous reactance as determined from this is a measure of the flux interlinkage in line with the poles, while the minimum reactance is the corresponding measure of interlinkage at 90 electrical degrees to the field. The ratio of these reactances in several small motors ranged from 2.5:1 to 3:1, indicating a corresponding ratio of maximum to minimum reluctance. Although a method of calculation which takes the difference in reluctance into account is not as simple as that explained in connection with Fig. 6, the calculations are by no means difficult.



Referring to Fig. 18 (in which only one of the polyphase windings is indicated) let  $\omega t$  stand for the angle between the axis of the coil and the field-poles. Assume the current in this coil to be

$$i = I_m \cos (\omega t - \alpha) \quad (1)$$

This current reaches maximum when  $\omega t = \alpha$ . Since the other phases carry currents which reach maximum at the same coil position,

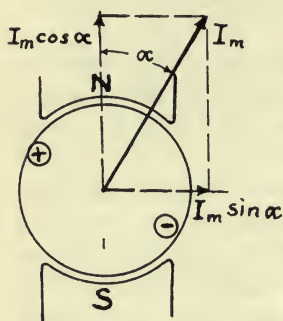


FIG. 18. Magnetizing forces of armature currents.

the effect of the polyphase winding is to produce a steady magnetizing force proportional to  $I_m$ , in the direction  $\alpha$  from the field axis. This has a component  $I_m \cos \alpha$  in the direction of the field-poles and a component  $I_m \sin \alpha$  at right-angles (or 90 electrical degrees) to the main field. Let  $A$  stand for the factor of proportionality between the magnetizing current and field-strength in the direction of the field structure, and  $B$  the corresponding factor for cross-magnetization. (Owing to the relatively high reluctance at 90 electrical degrees from the field-poles,  $B$  is much

less than  $A$ .) The main and cross-components of field due to armature currents are then

$$F_a = A i_m \cos \alpha \quad (2)$$

and

$$F_b = B I_m \sin \alpha \quad (3)$$

For brevity, we shall let  $I_1$  stand for  $I_m \cos \alpha$  and  $I_2$  stand for  $I_m \sin \alpha$ , whence

$$F_a = A I_1 \text{ and } F_b = B I_2$$

If d-c excitation is provided, such as to produce a field  $F$ , the total main field will be

$$F + F_a = F + A I_1$$

The field flux surrounded by the coil depends on the coil position, being equal to  $(F + F_a) \cos \omega t$  for the component of field in line with the poles, and  $F_b \sin \omega t$  for the component at right-angles to the poles.



Two components of voltage will be produced, proportional to rates of change of flux interlinkage of the coil with the two components of field flux.

$$e_m = -N \frac{d}{dt} (F + F_a) \cos t = \omega N (F + F_a) \sin \omega t \quad (4)$$

$$e_b = -N \frac{d}{dt} F_b \sin \omega t = -\omega N F_b \cos \omega t \quad (5)$$

in which  $N$  is a constant of proportionality depending on the number of turns.

The total induced or generated voltage is

$$\begin{aligned} e_v = e_m + e_b &= \omega N (F + F_a) \sin \omega t - \omega N F_b \cos \omega t \\ &= \omega N (F + AI_1) \sin \omega t - \omega N BI_2 \cos \omega t \end{aligned} \quad (6)$$

The vector expression for this generated voltage is

$$E_g = -\omega N BI_2 - j\omega N (F + AI_1) \quad (7)$$

The vector expression for the current  $i = I_m \cos (\omega t - \alpha)$  is

$$I = I_m \cos \alpha - jI_m \sin \alpha \text{ or } I_1 - jI_2 \quad (8)$$

As may be verified by reference to almost any text on a-c theory, the power (per phase) converted from electrical to mechanical energy is equal to the real component of  $-E_g$  multiplied by the real component of  $I$  plus the products of the imaginary components of  $-E_g$  and  $I$  (but not including the  $j^2$  in the product), whence:

$$P = \omega N BI_1 I_2 - \omega NI_2 (F + AI_1) \quad (9)$$

The total impressed or terminal voltage must provide a component equal and opposite to the generated voltage and also overcome the resistance and leakage reactance drops in the windings, whence

$$\begin{aligned} E_t &= -E_g + (I_1 - jI_2)(R + j\omega L') \text{ in which } L' = \text{leakage inductance} \\ &= j\omega NF + I_1(R + j\omega L' + j'\omega NA) + I_2(\omega NB + \omega L' - jR) \end{aligned} \quad (10)$$

Let us apply this to a specific case, for which we shall take  $A = 1.0$ ,  $B = 0.4$ ,  $N = 100$ ,  $F = 1.0$ , or  $NF = 100$ ,  $R = 10$ ,  $L' = 10$ . As the first condition, assume  $E_t = 100$  and  $\alpha = 20^\circ$  (motor action).

In Fig. 19(a), the in-line magnetizing component of current  $I_1$  is to be laid off on the horizontal axis, and the cross-magnetizing component  $I_2$  is vertical. The component of voltage  $j\omega NF$ , due to the d-c field excitation, is also vertical, and  $E_t$  is laid off  $20^\circ$  ahead of  $j\omega NF$ . It should be noted that the voltage  $j\omega NF$  is a definite index

of armature phase position. At no load (and with field adjusted to make  $\omega NF$  equal to  $E_t$ , or, in other words, zero armature current),  $E_t$  and  $j\omega NF$  coincide, whence the angle between  $j\omega NF$  and  $E_t$  is the angle of armature deflection, or the angle  $x$  of Fig. 6. With other amounts of excitation or allowing for motor losses, the actual no-load running position would not give exactly  $x = 0$ , and the no-load value of  $x$  must be taken into account in figuring stiffness.

Each ampere of  $I_1$  requires a voltage  $R + j\omega L' + j\omega NA$  (from equation 10) and each ampere of  $I_2$  requires a voltage  $\omega NB + \omega L' - jR$ . These are shown as the respective impedances  $Z_1$  and  $Z_2$  of Fig. 19(a). The voltage components corresponding to  $I_1$  and  $I_2$  may now be found graphically, by connecting the end of the  $j\omega NF$  vector to the end of the  $E_t$  vector by means of two lines drawn parallel to  $Z_1$  and  $Z_2$ , respectively. In this instance these  $IZ$  drops are opposite in direction to the reference vectors  $Z_1$  and  $Z_2$ , whence both  $I_1$  and  $I_2$  are negative. Scaling off the voltage drops gives  $I_1 Z_1 = -33.5$  and  $I_2 Z_2 = -11.5$ , and from the magnitudes of  $Z_1$  and  $Z_2$  (110 and 51, respectively) we find  $I_1 = -0.104$  and  $I_2 = -0.655$ . The two components and their resultant current  $I_1$  are shown in the figure. It is next in order to find the total generated voltage. This may be easily found from equation 7 and the now known values of  $I_1$  and  $I_2$ . The power may be found from equation 9 or by ascertaining by scale the magnitude of  $-E_g$  and the projection of  $I$  (total) on  $-E_g$  and multiplying these together.

For other values of displacement angle  $x$  or of field excitation  $F$ , we do not need to repeat the laying out of  $Z_1$  and  $Z_2$ , but may simply lay out the  $j\omega NF$  and  $E_t$  vectors for the new conditions and connect these by lines parallel to the original  $Z_1$  and  $Z_2$  vectors. This has been done in Figs. 19(b, c, d, e, and f). Fig. 19(b) is for an ideal case of no load, or for zero current. Fig. 19(c) illustrates generator action.

If no field excitation is supplied,  $j\omega NF$  in equation 10 drops out, and we draw the  $I_1 Z_1$  and  $I_2 Z_2$  lines to give  $E_t$  as their resultant. The large exciting current is evident in all three conditions of load.

*Positive and Negative Damping.*—In the body of the paper there is a discussion of positive and negative damping, based on the general proposition that an increase in generated voltage will decrease power intake. How pronounced this effect is depends on the ratio of resistance to reactance. With small machines in which the resistance is considerable it is important. Even in small machines, however, the

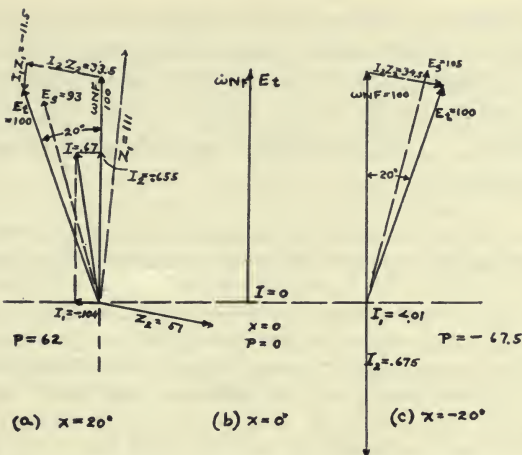


FIG. 19. Voltage, current, and displacement relations with d-c excitation.

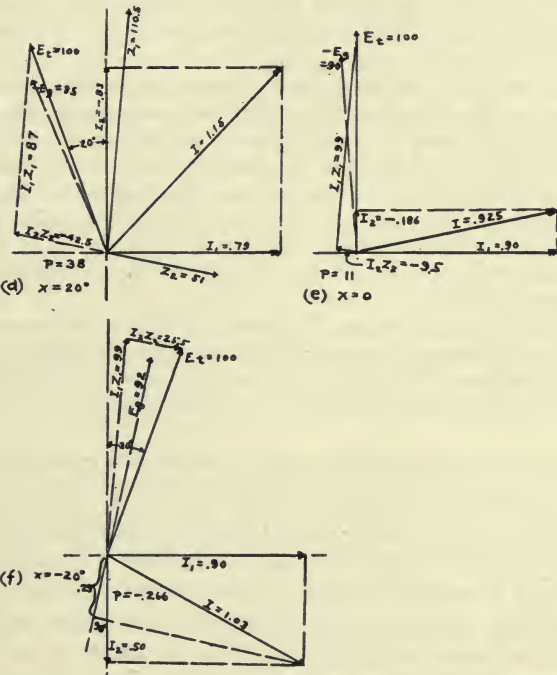


FIG. 19 (Cont.). Voltage, current, and displacement relations without d-c excitation



ratio of reactance to resistance is generally such that an increment of voltage has more effect on the current component in quadrature with the voltage increment than it has on the current component in phase with this voltage. Some of the results of this relationship will be mentioned here. It will be helpful if we restate the general nature of the field fluctuations.

(1) When a synchronous machine oscillates there is a large fluctuation in the cross-field (which varies with the momentary magnitude of the rotor phase position).

(2) There is also a fluctuation in the main field, the field being weakest at high motor load. This effect is exaggerated by high armature resistance.

(3) All the vector diagrams shown represent steady state conditions. If the forward and backward rotor displacements take place very slowly, the conditions will be substantially the same at a given displacement angle whether this angle is increasing or decreasing, and this means that the torque *vs.* position relationship is that of a pure stiffness. On the other hand, if the period of oscillation is comparable with the time-constant of the field, then the strengths of the magnetic fields lag behind the values which would be indicated by the calculations for steady-state, or, in other words, are intermediate between the values which would be calculated for the existing deflection, and for the deflection which just preceded this.

(4) The time-lag in field-strengths is inherent in the fact that the magnetic fields represent stored energy, and energy must be supplied or taken out in order to change the field strength. Coils surrounding the field flux provide the path through which energy is supplied or abstracted. Stationary closed circuits (main field winding and damping windings) decrease the magnitude of the flux changes and also increase the time-lag. In the case of a polyphase winding, whose coils in succession surround the field flux, the magnetic energy is in part spent in winding resistance (as in the case of the stationary winding) and in part transferred to the quadrature field.

(5) The time-constant for the cross-field is considerably shorter than for the main field, partly because the reluctance in this axis is high, and partly (in the case of a machine designed for d-c excitation) because the main field winding generally provides a lower resistance path than the damping winding.

There are three effects which cause the conditions during an oscillation cycle to depart from those calculated for the same displacement angle by the general steady-state theory. These are best expressed as components of voltage (or voltage "increments") which would not be present in the case of extremely slow changes in deflection. We are interested primarily in the voltage departures from normal during the part of the cycle when the deflection is changing, for it is deviations in torque at these times that produce positive or negative damping, rather than mere changes in stiffness.



(a) The change in speed causes a change in generated voltage for any given field-strength. This voltage increment is in phase with  $E_g$ . (It might be considered that  $\omega$  is momentarily increased or decreased in equation 7.)

(b) The main field-strength is below normal when the rotor is catching up, and above normal when the rotor is falling back. This is due to the persistence of the field, which is normally weak at high motor load and strong at low motor load. (This type of fluctuation is exaggerated by high winding resistance, and it becomes small or may even reverse in direction when the machine is acting as a generator.)  $a$  and  $b$  have been discussed in the paper proper.

(c) A changing field causes a voltage in the coils surrounding it, proportional to the rate of change of field. This is analogous to the voltage of self-induction in a stationary closed circuit. Suppose, for example, that the field  $F_a$  (which is produced by  $I_1$ ) is decreasing exponentially so that it would be expressed as  $F_a e^{-kt}$ . The magnetic flux surrounded by the rotating armature coil would be  $F_a e^{-kt} \cos \omega t$ . Differentiating this to find the induced voltage gives

$$-\frac{d}{dt} (F_a e^{-kt} \cos \omega t) = -F_a (-e^{-kt} \sin \omega t - k e^{-kt} \cos \omega t) \quad (11)$$

which contains the sine component as in equation 4, proportional to the value of field at the moment, and also a cosine component in phase with the magnetizing current  $I_1$ . Were it possible to eliminate reactance in the armature windings, leaving only resistance, this induced voltage would cause the currents in the poly-phase winding to affect the field flux in exactly the same way as would a stationary winding of the same resistance. With ordinary ratios of resistance to reactance, there is some tendency for the current surrounding any field to hold its value when a changing deflection would tend to make the current change. If the field is surrounded by a stationary closed circuit as well as by the armature coils, the short-circuited turn effects are shared by the two, the field-strength fluctuations are reduced, and the reactance of the armature windings is greatly reduced.

Each of the three voltage increments just described may be resolved into components which will cause magnetizing and cross-magnetizing or power currents to flow (*i. e.*, components of current parallel with  $I_1$  and  $I_2$ , respectively). With usual values of resistance and reactance the voltage increment would have more effect on the current in quadrature than on the current phase with it. Thus (considering only the quadrature currents):

Excess field-strength produces an increment of voltage opposite to the motor power current and causes demagnetizing current to flow in the armature.

Excess speed also causes demagnetizing current.

Decreasing main field causes generator-action power current.

Decreasing motor cross-field causes magnetizing current.

Decreasing generator cross-field causes demagnetizing current.

Although the reaction of the power components of current with the main field are the chief factors in determining torque, it is necessary, in studying damping, to take into account also the reactions of the magnetizing (or demagnetizing) currents with the cross-fields, and

by way of establishing polarity we may state the rule that magnetizing current reacts with motor cross-field to cause a retarding torque.

On the basis of the above-described relationships, we may tabulate (Table II) the deviations of speed, current, flux, and torque, using the symbol + to indicate a value above the normal or steady-state value for the same deflection, and a - sign to indicate an opposite effect. The symbols in the columns represent the conditions: (1) as the

TABLE II

	Motor Load			Generator Load		
			Damping			Damping
Deviation of speed from normal	+	-		+	-	
Main field (increasing or decreasing)	Inc.	Dec.		?	?	
Cross-field (magnitude, disregarding sign)	Dec.	Inc.		Inc.	Dec.	
$\Delta F_a$ deviation of main field from normal for that position	-	+		?	?	
I Effect on motor-power current of						
(a) $\Delta E_{gv}$ —voltage caused by speed change *	-	+	+	-	+	+
(b) $\Delta E_{gf}$ —change in generated voltage due to deviation of main field from normal strength *	+	-	-	?	?	
(c) $dF_a/dt$ —rate of change of main field Q	+	-	-	?	?	
(d) $dF_b/dt$ —rate of change of cross-field *	+	-	-	+	-	-
II Effect on magnetizing current of						
(a) $\Delta E_{gv}$ —voltage due to speed deviation Q	-	+	-	-	+	+
(b) $\Delta E_{gf}$ —deviation from normal field-strength Q	+	-	+	+	-	-
(c) $dF_a/dt$ —rate of change of main field *	-	-	-	?	?	
(d) $dF_b/dt$ —rate of change of cross-field Q	+	-	+	+	-	-

rotor swings through average position in forward direction and (2) as rotor swings through same position in its backward swing. The positive or negative damping for each factor is indicated.

A question mark (?) is shown in the generator load columns in the case of factors which depend on the effect of load on field-strength. A glance at Fig. 6 will show that the direction of the change in magnetizing current with generator load can not be stated unless conditions are specified with exactness, but in any case the changes are relatively small.

In the cases of items marked with an asterisk, the voltage producing the effect is in phase with the current component under consideration. The magnitude of the effect on the current is almost directly proportional to the resistance part of the winding impedance, becoming almost negligible in the case of machines with low winding resistance. Only one of the \* factors gives positive damping, and three give negative damping of motors, which again emphasizes the desirability of low resistance.

In the cases of the items marked  $Q$  the voltage is in quadrature with the current component in question. Here a given voltage causes a larger current change.

The torque effects of the magnetizing component of current are based on the reaction between this current and the cross-field, which reverses sign between motor and generation action. These effects practically disappear at light load.

Particular attention is directed to item  $I(d)$ . If a motor has high resistance windings and no damper grids, very strong negative damping or instability is to be expected. Low winding resistance reduces this negative damping, and a stationary damping winding not only cuts down the voltage in the armature which causes the harmful current to flow, but also affords powerful positive damping in the manner described in the earlier part of the paper.

It has appeared that the tendency toward instability becomes greater with rotor deflection in the direction corresponding to motor load. Comparison of diagrams  $b$  and  $e$  of Fig. 19 for the unexcited machine shows that at zero deflection there is considerable motor power in the unexcited machine, as compared with none in the excited machine. This means (at least for light motor loads) that the operating range for the unexcited machine is farther from the region in which the field-strength fluctuations are large (with resulting tendency to encounter negative damping). This accounts in part



for the better damping which we observed when the motor had low d-c excitation or none at all.

While this discussion of damping factors that we have given does not enable one to evaluate them, it serves to show that negative damping is by no means a fiction of the imagination, and that in such critical applications as are encountered in the picture industry engineers should not be satisfied with merely specifying a synchronous motor of adequate rating, but should give most careful consideration to the type of motor and the conditions of operation; and would do well also to subject motors which they contemplate using to thorough tests, to make sure that the machine is one of optimum design.

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## NOTE ON THE KEEPING OF HYDROGEN PEROXIDE-AMMONIA HYPO ELIMINATOR SOLUTIONS

*This is an addition to the paper on "The Elimination of Hypo from Photographic Images," by J. I. Crabtree, G. T. Eaton, and L. E. Muehler, published in the November, 1940, issue of the JOURNAL on p. 484.*

In connection with the preparation and use of the hydrogen peroxide-ammonia hypo eliminator solutions described in the November issue, it is important to realize that such solutions give off oxygen continuously, but in spite of this decomposition, they possess a satisfactory exhaustion life. However, the mixtures must not be stored in closed containers at any time. The hypo eliminator solution should be mixed just before use and kept in open containers until discarded.

When storing the 3 per cent hydrogen peroxide solution used for preparing the hypo eliminator solution, the following precautions should also be taken:

(1) The solution should be stored in a brown bottle away from daylight and in a cool place since both heat and light accelerate the decomposition of hydrogen peroxide.

(2) An ordinary loose-fitting cork rather than a screw cap type of stopper should be used.

(3) If the bottle is large, a small-bore glass tube should be inserted through the cork to permit the oxygen gas to escape and thus avoid the possibility of pressure being developed, resulting in bursting of the bottle.

(4) Large-scale users should consult with the manufacturers on precautions in handling and storing hydrogen peroxide solutions.



**REPORT FROM**

*The Research Council of  
The Academy of Motion Picture Arts and Sciences  
Hollywood, Calif.*

**Report on Arc Lamp Noise Tests, Including Recommendations for Reducing Set Noise Due to Arc Lamps**





## REPORT ON ARC LAMP NOISE TESTS\*

INCLUDING RECOMMENDATIONS FOR REDUCING SET NOISE DUE TO  
ARC LAMPS

RESEARCH COUNCIL, ACADEMY OF MOTION PICTURE ARTS  
AND SCIENCES\*\*

This report contains an explanatory account of the various tests conducted by the Research Council Committee on set equipment noise conditions, upon which the Council's recommendations for reducing set noise due to arc lamps are based.

The principal problem of the Committee was to determine the possibilities for reducing arc lamp set noise in color photography to a level comparable with the noise level on "black-and-white" sets.

First consideration of the problem divided the sources of noise from arc lamps as follows:

- (1) Noises from the carbons themselves during the burning process due to
  - (a) Commutator ripple present in the power supply.
  - (b) Non-uniformities in the physical structure of the carbon.
- (2) Noise from the arc lamp rotating parts, *i. e.*, the motor and feed mechanism.
- (3) Expansion and contraction noises of the lamp house and associated parts.

In connection with commutator ripple in the power-supply, preliminary investigation showed that all the studios are using choke-coils and/or condensers in the power-supply system, as recommended previously by the Academy.<sup>1</sup>

Previous noise-level tests on arc lamps were studied and preliminary tests conducted to determine the proper testing procedure. Subsequently tests as outlined later in this report were conducted at Metro-Goldwyn-Mayer Studios.

Inasmuch as production requirements are oftentimes very different from testing procedure, tests of actual production conditions were made, and "listening tests" of release prints made from negatives shot under production conditions using different types of negative

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\*Released January 2, 1941.

\*\*Hollywood, Calif.

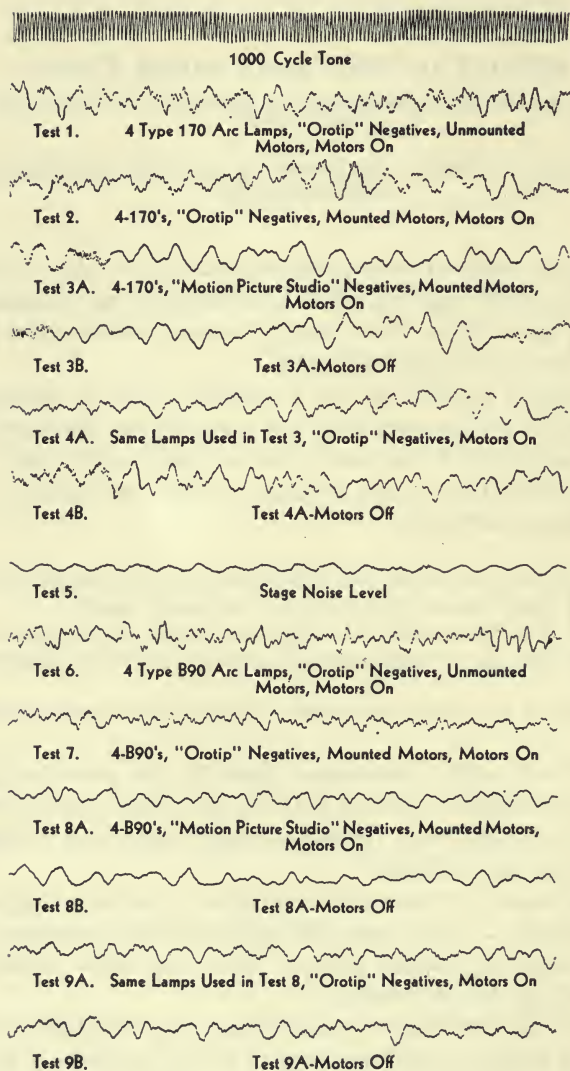


FIG. 1. Arc lamp noise tests; microdensitometer analyses, reproduced as recorded (Research Council Committee on Set Equipment Noise Conditions).

carbons and arc lamps acoustically treated to reduce noise level (as contrasted with untreated lamps) were made.

About this time reports of difficulties encountered in maintenance of acoustically treated arc lamps were brought to the attention of the

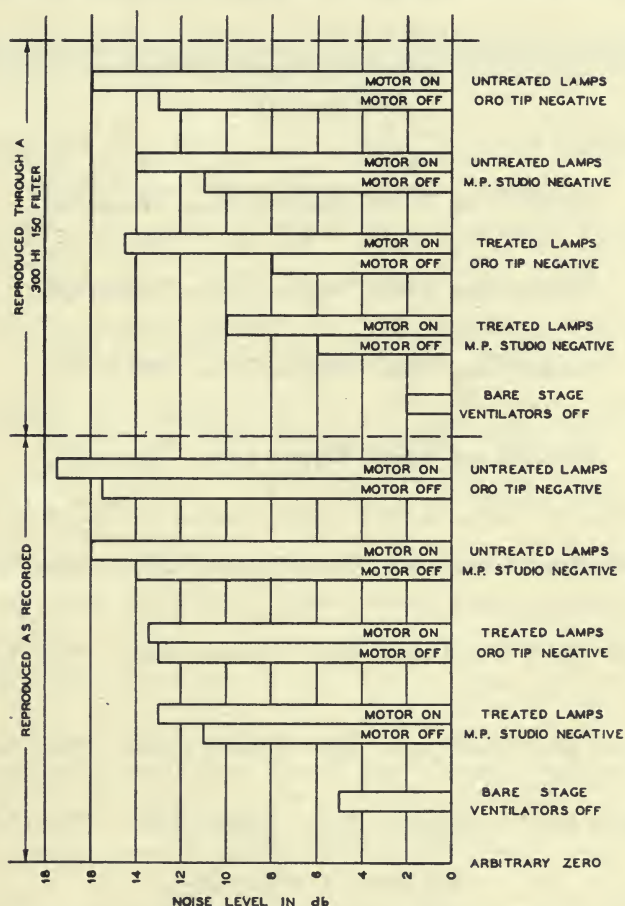


FIG. 2. Arc lamp noise tests; recording volume indicator, average levels (Research Council Committee on Set Equipment Noise Conditions).

Committee. Consequently a general meeting was held, to which studio sound and electrical department representatives, Technicolor representatives, and representatives of the equipment and carbon manufacturers were invited.

During the general discussion at the meeting, the following technical points were brought out:

(a) That although acoustical treatment of the arc lamps had introduced difficulties in lubrication and maintenance of the lamps, these had been minimized

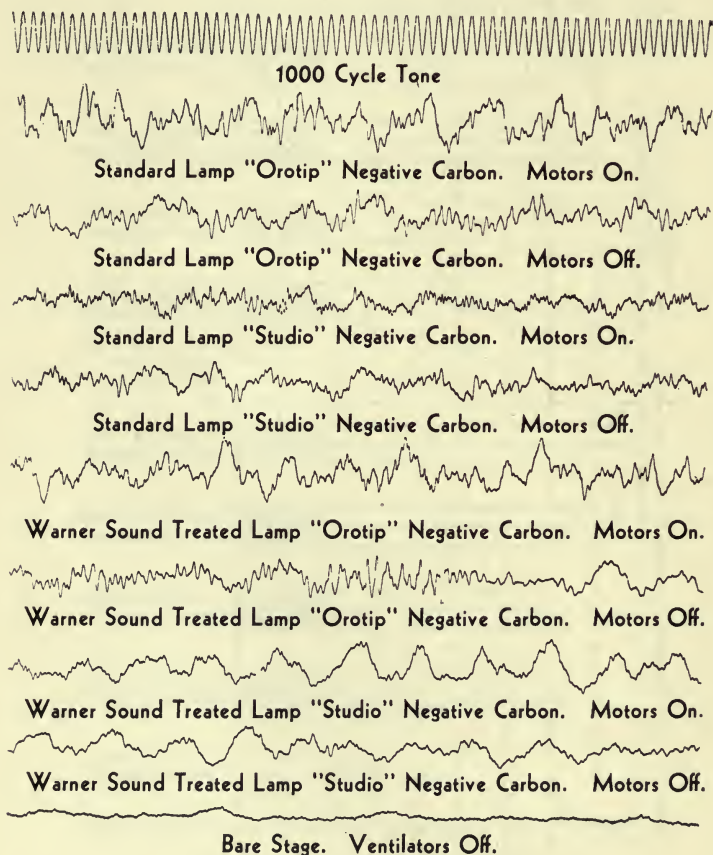


FIG. 3. Arc lamp noise tests; microdensitometer analyses, reproduced as recorded—no filter in circuit (Research Council Committee on Set Equipment Noise Conditions).

by the replacement of small switches and by other minor mechanical alterations which had eliminated the sources of these difficulties.

(b) That these mechanical and lubrication troubles were completely eliminated if the acoustically treated lamps were given careful periodic service, but



if production requirements interfered with this periodic service, mechanical troubles would start to develop after a week or ten days of continuous use.

(c) That too much oil on the lamp bearings led to operation difficulties. Deterioration of the oil due to higher temperatures existing in the acoustically

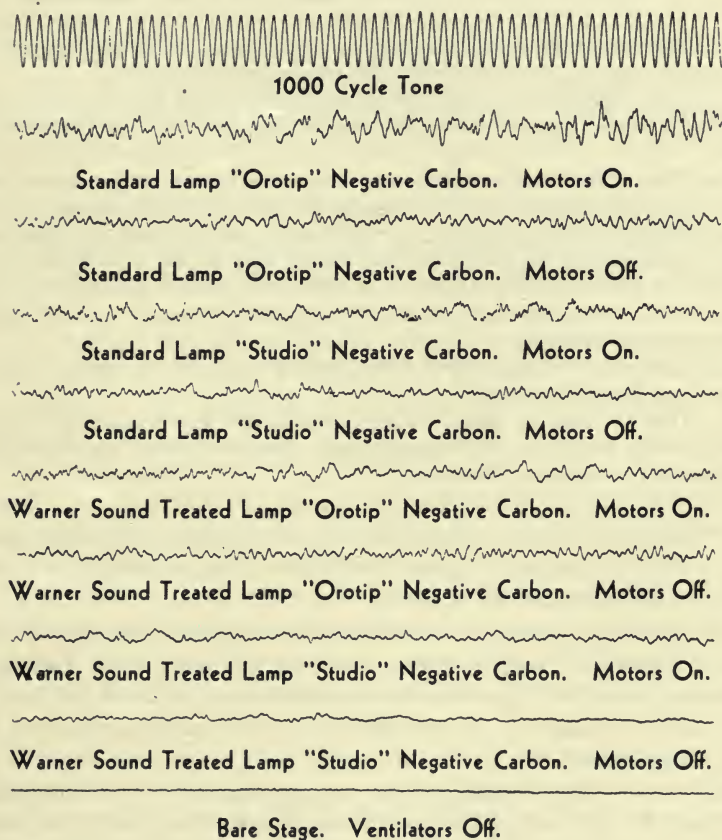


FIG. 4. Arc lamp noise tests; microdensitometer analyses, reproduced through 300-Hi-150 filter (Research Council Committee on Set Equipment Noise Conditions).

treated lamps reduced the oil to a gummy mass which gathered dust and dirt. It was suggested that the use of oilless bearings would probably minimize such difficulties.

(d) That recently designed acoustically treated arc lamps had a lower noise level and less mechanical troubles because of:

- (1) A re-design of the ventilation cap (which also reduced sound difficulties by diverting the sound from the microphone).
- (2) The installation of a tray device to pick up particles of copper dropping off the carbon, and
- (3) A re-design of the back of the lamp to include a lattice opening and a diffuser to reflect the sound away from the microphone.

(e) That one of the studios had been using arc lamps completely treated with acoustical material, but had encountered no ventilation trouble.

(f) That experiments had been made using acoustically treated lamps of the so-called "broad" type and that this treatment had also helped to reduce motor noise.

(g) That the principal trouble encountered at some of the studios seemed to be from motor and feed noise and that a reduction in lamp voltage seemed to minimize these difficulties. However, it was brought out that light tests had been made demonstrating the fact that if the motors were turned off or slowed down (a result of reducing the voltage) the illumination dropped off in direct proportion with time, the illumination being reduced about 50 per cent at the end of approximately 5 minutes.

(h) That the new type carbon is satisfactory so far as the quality and the quantity of light is concerned.

(i) That new type arc lamps had been designed and were being manufactured, incorporating several of the improvements discussed which contributed less noise and gave smoother illumination.

It was the consensus of all present at this conference that the use of acoustically treated arc lamps should be recommended by the Research Council to all the studios.

In addition, it was the consensus that the new "Motion Picture Studio Negative" contributed to a lower set noise level, but more important, resulted in a less objectionable noise as heard by the ear, and that consequently its use should also be recommended by the Research Council.

However, before making these recommendations, the Committee decided that the new "Motion Picture Studio Negative" should be used in all lamps exclusively throughout a complete Technicolor production.

This production test was made at 20th Century-Fox Studios on the picture *The Return of Frank James* with "Motion Picture Studio Negative" carbons.

Comparative listening tests were made between a print of this production, and a print from an earlier color production (*Jesse James*) on which acoustically treated arc lamps with the previous type negatives were used. These listening tests indicate conclusively that a

reduction in effective noise level is secured through the use of the new carbons, in lamps with feed motors mounted on rubber supports to mechanically insulate the motor from the lamp proper.

Also, additional tests as outlined later in this report have been completed at Paramount Studio, to determine the effectiveness of certain mechanical improvements recently made in arc lamp design.

There has been considerable progress in the solution of the problem of lamp noise as evidenced by the fact that the standard of measurement is now a treated lamp with the "Orotip" carbon. The results of improvements such as the "Motion Picture Studio Negative" and the shock-proof mounting of motors are evident when subject to comparison with the new standard. This progress is evident when this standard is contrasted with the standard first used by the Committee—*i. e.*, a lamp with old type carbons and unmounted motors.

The tests at Paramount Studios definitely demonstrate the value of the use of the "Motion Picture Studio Negative" carbon as well as the value of the shock-proof mounting of feed-mechanism drive motors.

The new negative carbon is now available in quantities, but it should be pointed out that these new carbons, for the same type lamps, are of a slightly larger size and their use necessitates a minor mechanical change in the arc lamp feed mechanism.

In general, the recommended acoustical treatment takes the form of a lining of some type of sound-absorbing material, so installed in the lamp that ventilation is not reduced materially. The type of acoustical material used should not be affected by the temperature of the arc and should not deteriorate with use.

A number of the studios have done considerable experimental investigation to determine the best type of treatment. The results of these experiments, made principally by Warner Brothers, Paramount, Metro-Goldwyn-Mayer, and 20th Century-Fox Studios, and by the Mole-Richardson Company, have been offered through the Research Council to any other company wishing to conduct further experimentation or to adopt one or another of the methods worked out by the above companies.

The exhaustive listening and noise-level measurement tests conducted by the Committee have proved the following facts:

(1) That shock-proof mounting of the feed-mechanism drive motors reduces the mechanical noise normally present in an arc lamp during operation. With



mounted motors, no difference in noise is apparent with the motors "on" or "off," except that the noise of the arc itself apparently increases with the motor "off."

(2) That acoustical treatment of the arc lamps reduces the overall noise level through sound absorption.

(3) That the use of a carbon with burning and lighting properties similar to the new "Motion Picture Studio Negative" carbon results in noise less objectionable as heard by the ear.

This Committee therefore recommends that the Research Council inform each producing company of the effectiveness of the shock-proof mounting of feed-mechanism motors, acoustical treatment, and the use of the new "Motion Picture Studio Negative" carbon for all arc lamps used in production set illumination.

In conclusion the Committee wishes to acknowledge the helpful coöperation of the Warner Brothers Studio Sound Department under Nathan Levinson, the 20th Century-Fox Studio Sound Department under E. H. Hansen, and the Paramount Studio Sound Department under Loren Ryder for assisting in conducting the tests and experiments outlined above; of Charles Handley and the National Carbon Company; Elmer Richardson, F. C. Coates, and the Mole-Richardson Company; Homer G. Tasker and William Miller of Paramount Studios; and William Mueller of Warner Brothers Studios, all of whom have coöperated in the work of the Committee.

We are including with this report detailed outlines of the procedures and results of the various tests conducted by the Committee in the course of our investigation.

T. T. MOULTON,  
*Chairman, Committee on Set Equipment Noise Conditions*

ARC LAMP NOISE TESTS  
*Paramount Studio*  
*Monitor Room Stage 14*  
*July 31, 1940*

*Purpose.*—The purpose of these tests was to prove or disprove the advantages of shock-proof mounting of the feed-mechanism drive motors and to obtain further information on the advantage of using carbons of the type of the "Motion Picture Studio Negative" employing an improved noise-level reference—*i. e.*, lamps sound-proofed



by the use of acoustical treatment (compared to the noise-level reference [untreated lamps] used in the tests of May 31, 1938).

*Procedure.*—(1) Four treated Type 170 arc lamps were placed on the circumference of a quarter circle of  $7\frac{1}{2}$ -ft radius, with the microphone at the center of the circle, 3 feet above the level of the lamps.

(2) One lamp was struck and allowed to settle, and a noise-level measurement with the General Radio noise-level meter No. 638 was made 3 feet in front of the lamp (Position A)

(a) with a 40-db weighting network in the circuit, and

(b) with the network removed from the circuit.

The microphone was mounted on a regulation tripod, at a height of approximately  $3\frac{1}{2}$  feet from the stage floor.

(3) The above measurements were repeated on the remaining three lamps of this group.

(4) Measurements were made at the side (Position B) and behind (Position C) the fourth lamp, with the microphone again at a distance of 3 feet from the center of the lamp.

(5) Measurements, with and without the weighting network in the circuit, were made of the stage noise level.

(6) All four lamps were struck and allowed to settle. The recording system gain was adjusted to obtain a noise signal equal to average dialog level for this group of lamps. This level was then checked with the oscilloscope, which had been previously calibrated for clash.

(7) The noise level of these four lamps was then recorded.

(8) Procedures 1 to 7, inclusive, were repeated for four Type 170 lamps having mounted motors and trimmed with "Orotip" negatives.

(9) Procedures 1 to 7, inclusive, were repeated for four Type 170 lamps having mounted motors and trimmed with the "Motion Picture Studio Negative" carbons. The recording includes 50 feet with motors running, a 5-ft break and 20 feet with motors off.

(10) Procedure 9 was repeated with identical lamps but trimmed with "Orotip" negatives.

(11) Measurements of the stage noise level with and without the weighting network in the circuit were made.

(12) The stage noise level was recorded.

(13) Identical tests as outlined in procedures 1 to 10, inclusive, were made using Type B90 lamps.

*Note:* The recording system gain remained unchanged throughout the tests.

## ARC LAMP NOISE-LEVEL MEASUREMENTS

Studio	Lamp	Type	Motor Insulated	Micro-phone Position	Noise-Level Characteristic Flat Char.	40 Db Char.	Negative Trim
<i>Para No. 1</i>		170	No	A	44	40	Orotip
<i>Para No. 2</i>		170	No	A	46	38	Orotip
<i>MGM No. 3</i>		170	No	A	43	31	Orotip
<i>MGM No. 4</i>		170	No	A	42	32	Orotip
<i>MGM No. 4</i>		170	No	B	42	30	Orotip
<i>MGM No. 4</i>		170	No	C	44	30	Orotip
Stage Noise					33	26	

*Take No. 1 (50 feet)*—Four Type 170 Arc Lamps (Paramount Nos. 1 and 2, plus MGM Nos. 3 and 4) all burning; "Orotip" negative trim, unmounted motors.

<i>Para No. 5</i>	170	Yes	A	42	29	Orotip
<i>Para No. 6</i>	170	Yes	A	42	31-37	Orotip
<i>Para No. 7</i>	170	Yes	A	43	40	Orotip
<i>Para No. 8</i>	170	Yes	A	43	30	Orotip
<i>Para No. 8</i>	170	Yes	B	45	40	Orotip
<i>Para No. 8</i>	170	Yes	C	43	33	Orotip
<i>*Para No. 7</i>	170	Yes	A	48	41	Orotip
<i>RKO No. 1</i>	170	Yes	A	45	30	Orotip

*Take No. 2 (50 feet)*—Four Type 170 Arc Lamps (Paramount Nos. 5, 6, and 8 plus RKO No. 1) all burning; "Orotip" negative trim, mounted motors.

\* Lamp No. 7 replaced—did not have mounted motor.

<i>RKO No. 1</i>	170	Yes	A	42	27	MPSN**
<i>WB No. 1</i>	170	Yes	A	43	28	MPSN**
<i>RKO No. 2</i>	170	Yes	A	44	29	MPSN**
<i>WB No. 2</i>	170	Yes	A	40	28	MPSN**
<i>WB No. 2</i>	170	Yes	A	46	30*	MPSN**
<i>WB No. 2</i>	170	Yes	B	41	28	MPSN**
<i>WB No. 2</i>	170	Yes	C	42	28	MPSN**

\* Blower on.

\*\* MPSN—"Motion Picture Studio Negative" Carbon.

*Take No. 3 (50 feet)*—Motors on, 5 feet dead track, and 20 feet motors off. Four Type 170 Arc Lamps (RKO Radio Nos. 1 and 2, plus WB Nos. 1 and 2); "Motion Picture Studio Negative" trim, mounted motors.

*Take No. 4 (50 feet)*—Motors on, 5 feet dead track, 50 feet motors off. Four Type 170 Arc Lamps (RKO Radio Nos. 1 and 2) all burning; "Orotip" Negative Trim, mounted motors.

Stage noise  
Stage noise

30 to 32 Flat Char.  
26 to 25, 40 db Char.

*Take No. 5 (50 feet)*—Stage noise level.

Studio	Lamp	Type	Motor Insulated	Micro- phone Position	Noise-Level Characteristic		Negative Trim
					Flat Char.	40 Db Char.	
<i>Para No. 1</i>		<i>B90</i>	No	<i>A</i>	39	26*	Orotip
<i>Para No. 2</i>		<i>B90</i>	No	<i>A</i>	45	33	Orotip
<i>Para No. 3</i>		<i>B90</i>	No	<i>A</i>	39	29	Orotip
<i>Para No. 4</i>		<i>B90</i>	No	<i>A</i>	39	28	Orotip
<i>Para No. 4</i>		<i>B90</i>	No	<i>B</i>	37	27	Orotip
<i>Para No. 4</i>		<i>B90</i>	No	<i>C</i>	39	27	Orotip

\* Motor off.

*Take No. 6 (50 feet)*—Four Type *B90* Arc Lamps (Paramount Nos. 1, 2, 3, and 4) all burning; "Orotip" Negative Trim, unmounted motors.

<i>Para No. 5</i>	<i>B90</i>	Yes	<i>A</i>	42	28	Orotip
<i>Para No. 6</i>	<i>B90</i>	Yes	<i>A</i>	40	32	Orotip
<i>Para No. 7</i>	<i>B90</i>	Yes	<i>A</i>	39	27	Orotip
<i>Para No. 8</i>	<i>B90</i>	Yes	<i>A</i>	37	26	Orotip
<i>Para No. 8</i>	<i>B90</i>	Yes	<i>B</i>	39	28	Orotip
<i>Para No. 8</i>	<i>B90</i>	Yes	<i>C</i>	39	28	Orotip

*Take No. 7 (50 feet)*—Four Type *B90* Arc Lamp (Paramount Nos. 5, 6, 7, and 8) all burning; "Orotip" Negative trim, mounted motors.

<i>RKO No. 1</i>	<i>B90</i>	Yes	<i>A</i>	37	25	MPSN
<i>RKO No. 2</i>	<i>B90</i>	Yes	<i>A</i>	36	25	MPSN
<i>WB No. 1</i>	<i>B90</i>	Yes	<i>A</i>	37	25	MPSN
<i>WB No. 2</i>	<i>B90</i>	Yes	<i>A</i>	39	26	MPSN
<i>WB No. 2</i>	<i>B90</i>	Yes	<i>B</i>	40	28	MPSN
<i>WB No. 2</i>	<i>B90</i>	Yes	<i>C</i>	40	28	MPSN

*Take No. 8 (50 feet)*—Motors on, 5 feet dead track, 20 feet motors off. Four Type *B90* Arc Lamps (RKO Nos. 1 and 2, plus WB Nos. 1 and 2) all burning; "Motion Picture Studio Negative" trim, mounted motors.

Stage noise

32

24

*Take No. 9 (50 feet)*—Motors on, 5 feet dead track, 20 feet motors off. Four Type *B90* Arc Lamps (RKO Nos. 1 and 2, plus WB Nos. 1 and 2) all burning; "Orotip" Negative Trim.

## ARC LAMP NOISE-LEVEL TEST RECORDINGS

*Warner Brothers Studio**July 18, 1939*

These tests were reviewed by the Committee, together with electrical and sound department representatives and others in Projection Room A at the Samuel Goldwyn Studios.

*Test No. 1*—Three Type 170 arc lamps, 28 Type 90, 2 scoops, and 7 broads trimmed with "Orotip" carbons, with motors on, were burning on the set.

*Test No. 2*—Identical with Test No. 1 with the motors off.

*Test No. 3*—Three Type 170 arc lamps and 28 Type 90 lamps trimmed with "Orotip" negatives, motors on, were burning on the set.

*Test No. 4*—Identical with Test No. 3, except with motors off.

*Test No. 5*—Three Type 170 arc lamps and 28 Type 90, trimmed with the "Motion Picture Studio Negatives," motors on, were burning on the set.

*Test No. 6*—Identical with Test No. 5, except with motors off.

*Test No. 7*—All lamps were turned off, and the stage noise level recorded to give a comparison.

## ARC LAMP NOISE TESTS

*Metro-Goldwyn-Mayer Studios**Stage 1**March 23, 1938*

*Purpose.*—(a) The purpose of these tests was to prove or disprove the advantages of the new type "Motion Picture Studio Negative" carbon compared to other types of negative carbon available for use in motion picture production, and

(b) To prove or disprove the advantages of acoustic treatment of lamps.

*Procedure.*—Ten Mole-Richardson untreated Type 170 arc lamps were placed on the circumference of a quarter circle of about 15-ft radius, at the center of which was placed a microphone hung approximately 4 feet above the lamp height.

Recordings were then made of the noise contributed by this bank of ten untreated lamps using both the "Orotip" Negative and the new type "Motion Picture Studio Negative" (through a standard recording channel as ordinarily used in production at Metro-Goldwyn-Mayer Studios, with a condenser microphone as normally used for



dialog recording—the recording channel flat from 30 to 8000 cps, with no dialog equalizer in the circuit, and with two bull chokes on the line to eliminate commutator ripple).

Ten Type 170 lamps as treated by Warner Brothers Studios were then placed in the identical positions formerly occupied by the untreated lamps, and a similar set of lamp noise recordings were made.

At the conclusion of the tests and after the stage had been completely cleared of equipment and personnel, a recording of the stage noise level was made at the same gain as used during the lamp noise recording tests (as indicated, see chart).

*Results.*—Average recording volume indicator levels as subsequently measured are indicated on the chart. In order to indicate the amount of low frequency present in the lamp noise, the recordings were reproduced both “as recorded” and “through a 300 HI 150 filter.”

These recordings were also analyzed on the microdensitometer as indicated in the charts.

*Note.*—An oscilloscope connected to the line between the bull choke and the lamp indicated no commutator ripple after the lamp had been turned on, with “motor on,” unless one lamp was burning improperly, in which case a decided ripple was indicated.

The oscilloscope also indicated a decided ripple during the “motor off” test, starting within about 30 seconds after the lamp had been turned on and tending to increase the longer the lamps were allowed to burn with the motors off.

#### REFERENCE

- <sup>1</sup> “Methods of Silencing Arcs” (Report of the Academy Producers—Technicians Committee) *Acad. Mot. Pict. Arts & Sci.* (May 7, 1930).

## CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

*The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C.*

### American Cinematographer

22 (April, 1941), No. 4

- |  |                              |
|--|------------------------------|
| A Reflection-Type Meter for Making Incident-Light Readings (pp. 158-159) | K. FREUND                    |
| Are We Afraid of Coated Lenses? (pp. 161, 199)                           | C. G. CLARKE                 |
| Handling Film on Distant Locations (pp. 162, 186)                        | G. R. KERSHNER               |
| An Improved Method for Analyzing Light-Tests (p. 163)                    | C. DEVINNA AND J. RUTTENBERG |
| Pioneering in Talking Pictures (pp. 164, 201-202)                        | L. DE FOREST                 |
| Freedom of the Seas—on a Sound Stage (pp. 165, 186)                      | A. GROT AND L. KUTER         |
| Bell & Howell's First Professional Sixteen (pp. 170, 192)                | W. STULL                     |

### British Journal of Photography

88 (February 21, 1941), No. 4216

Progress in Colour (pp. 92-93)

### Electronics

14 (March, 1941), No. 3

Fantasound (pp. 18-21)

### International Projectionist

16 (February, 1941), No. 4

- |  |   |
|--|---|
| Stereophonic Sound Reproduction (pp. 7-8)  | K. DE BOER                                |
| An Improved Trouble-Shooter for Audio Amplifier Work (pp. 11-12, 15-16)            | C. E. MERVINE                             |
| Mercury-Vapor Lamp Characteristics (pp. 17-19)                                     | H. K. BOURNE                              |
| What's Happened to Television? (pp. 21-22)   |   |
| Some Recent Developments in 8-Mm "Supres" Copper-Coated, H.-I. Carbons (pp. 24-25) | W. W. LOZIER, G. E. CRANCH, AND D. B. JOY |

### Kinotechnik

23 (January, 1941), No. 1

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|--|-----------------------------|
| Eine neue Trickaufnahmemaschine (A New Trick Taking Apparatus) (pp. 1-5)     | J. GERB AND R. SCHMIDT      |
| Ein neues Schwärzungsmessgerät (A New Density Measuring Apparatus) (pp. 5-8) | H. ECKELMANN AND R. SCHMIDT |

## 1941 SPRING CONVENTION

### SOCIETY OF MOTION PICTURE ENGINEERS

THE SAGAMORE HOTEL  
ROCHESTER, NEW YORK  
MAY 5th-8th, INCLUSIVE

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**Officers and Members Rochester Projectionists Local No. 253****HEADQUARTERS**

The headquarters of the Convention will be the Sagamore Hotel, where excellent accommodations and moderate rates are assured. A reception parlor will be provided as headquarters for the Ladies' Committee.

Hotel reservation cards mailed to the members of the Society several weeks ago should be filled out and mailed immediately to the Sagamore Hotel so that suitable accommodations may be reserved, subject to cancellation if unable to attend the Convention.

The following European-plan day rates are extended by the Sagamore Hotel to Society members and guests attending the Convention (all rooms are outside rooms with bath):

Room for one person	\$3.00 to \$5.00
Room for two persons, double bed	4.50 to 6.00
Room for two persons, twin beds	6.00 to 7.00
Suite accommodations, one to four persons	12.00 and up

The following hotel garage rates will be available to SMPE delegates and guests who motor to the Convention: 24-hr. inside parking, 75¢; outside parking (daily), 25¢.

The colorful *Sagamore Room* on the main floor of the Hotel offers special breakfast, luncheon, and dinner menus at moderate prices.

Golfing privileges at several Rochester country clubs may be arranged for either by the hotel management or at the SMPE registration headquarters.



## REGISTRATION

Convention registration and information headquarters will be located on the Sagamore Hotel roof, adjacent to the *Glass House*, where technical sessions and symposiums will be held.

Members and guests attending the Convention will be expected to register, and so help to defray the Convention expenses. Convention badges and identification cards will be provided for admittance to all regular and special sessions during the Convention. The identification card will also be honored through the courtesy of Loew's Theaters, Inc., at Loew's *Rochester* Theater and, through the courtesy of Monroe Amusements, Inc., at the *Palace*, *Regent*, and *Century* Theaters.

## TECHNICAL SESSIONS

All the technical sessions of the Convention will be held in the *Glass House* on the roof of the Sagamore Hotel with the exception of Wednesday morning and evening, as described below. Members should note that the banquet, which at past conventions has always been held on Wednesday evening, this time has been scheduled for Tuesday evening to permit holding a special meeting on Wednesday evening at the *Eastman* Theater.

Wednesday, May 7th, will be devoted to a joint meeting of the Acoustical Society of America and the SMPE, consisting of a symposium of papers by engineers of the Bell Telephone Laboratories in the morning and afternoon. In the evening a demonstration of stereophonic sound will be given by the Bell Telephone Laboratories at the *Eastman* Theater.

## LUNCHEON AND BANQUET

The usual Informal Get-Together Luncheon for members, their families, and guests will be held in the *Starlight Room* on the hotel roof on Monday, May 5th, at 12:30 P. M. Luncheon and banquet tickets should be procured when registering.

The 48th Semi-Annual Banquet and Dance will be held in the *Starlight Room* on the hotel roof on Tuesday evening, May 6th, at 7:30 P. M.: music and entertainment. Banquet tickets should be procured and tables reserved at registration headquarters by noon of Tuesday, May 6th.

## LADIES' PROGRAM

Mrs. C. M. Tuttle, *Convention Hostess*, and members of her Committee are arranging a very attractive program of entertainment for the ladies attending the Convention. A reception parlor will be provided for the use of the Committee during the Convention.

## PROGRAM

*Monday, May 5th*

- 9:00 a. m. *Sagamore Hotel Roof*  
Registration
- 9:30 a. m.-12:00 *Glass House, Hotel Roof*  
Technical session
- 12:30 p. m. *Starlight Room, Hotel Roof*  
Get-Together Luncheon for members, their families, and guests. Brief addresses by several prominent speakers
- 2:00 p. m. *Glass House, Hotel Roof*  
Technical session
- 8:00 p. m. *Glass House, Hotel Roof*  
Technical session

*Tuesday, May 6th*

- 9:00 a. m. *Sagamore Hotel Roof*  
Registration
- 9:30 a. m. *Glass House, Hotel Roof*  
Society Business  
Technical session
- 12:30 p. m. Luncheon period  
Open afternoon
- 7:30 p. m. *Starlight Room, Hotel Roof*  
Semi-Annual Banquet and Dance of the SMPE: addresses and entertainment: music, dancing, and entertainment

*Wednesday, May 7th*

*Joint Meeting of the Acoustical Society of America and the Society of  
Motion Picture Engineers*

- 9:30 a. m. *Eastman Theater*  
Stereophonic sound papers session
- 12:30 p. m. Luncheon period
- 2:00 p. m. *Glass House, Hotel Roof*  
Stereophonic sound papers session
- 8:00 p. m. *Eastman Theater*  
Stereophonic sound demonstration for the SMPE Convention and invited groups. Admission only by SMPE identification card, or special invitation card

*Thursday, May 8th*

- 10:00 a. m. *Glass House, Hotel Roof*  
Technical session
- 12:30 p. m. Luncheon period
- 2:00 p. m. *Glass House, Hotel Roof*  
Technical session

## ADJOURNMENT

W. C. KUNZMANN,  
Convention Vice-President

ABSTRACTS OF PAPERS OF THE  
SPRING CONVENTION

AT

ROCHESTER, N. Y.

MAY 5-8, 1941

*The Papers Committee submits for the consideration of the membership the following abstracts of papers to be presented at the Spring Convention. It is hoped that the publication of these abstracts will encourage attendance at the meeting and facilitate discussion. The papers presented at Conventions constitute the bulk of the material published in the Journal. The abstracts may therefore be used as convenient reference until the papers are published.*

A. C. DOWNES, *Editorial Vice-President*

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W. V. WOLFE

**Five New Models of 16-Mm Sound Kodascopes;** W. E. Merriman, *Eastman Kodak Co.*, Rochester, N. Y.

A new line of Eastman 16-mm sound projectors identified by the model numbers *F*, *FB*, *FB-25*, *FS-10*, and *FB-40* will be described. The picture mechanisms and sound-heads of all models are identical. The difference among the models lies in the finish, the carrying cases, the power output of the amplifier, and the speaker equipment. The first three models will operate on alternating or direct current; the last two are for 50-60-cycle duty. Some of the standard features of these projectors are a 750-watt projection lamp and a 2-inch projection lens of  $f/1.6$  aperture. There is a focus adjustment on the scanning optics to permit satisfactory reproduction from either reversed negative or positive contact prints. A carefully designed rotary stabilizer is common to all models. A rotary snap switch, which turns on the pilot light, motor, and projection lamp in the proper sequence, is also standard equipment.

**Air-Conditioning Safety Device for Theaters;** E. R. Morin, *Connecticut State Police*, Hartford, Conn.

A new fire damper release and method of preventing smoke from being recirculated or pumped into a theater auditorium through the air-conditioning system in the absence of heat or flame has just been developed by the Motion Picture Division of the Connecticut State Police, and will be described in the paper.

**Some Properties of Polished Glass Surfaces;** F. Jones, *Bausch & Lomb Optical Co.*, Rochester, N. Y.



A discussion of work done at Mellon Institute as the Bausch & Lomb Fellow on the investigation of the durability of polished glass surfaces exposed to ordinary atmospheric attack; efforts to perfect accelerated tests so as to permit rapid determination of the durability characteristics of different kinds of glass; the application of this phenomenon to increasing light transmission; and to the artificial stabilization of surfaces on glass normally not very durable.

**Improvements in Methods of Surface Treatment of Lenses;** W. C. Miller, *Vard Mechanical Laboratories, Pasadena, Calif.*

As early as 1892 it was known that the reflectivity of polished glass surfaces was reduced and the light transmission increased when a suitable thin film was present on the surface of the glass. Many efforts to produce such a thin film artificially met with only partial success. In the last five years two different methods were discovered which achieved the desired results. Only one of the processes, however, was satisfactory for commercial application. Great improvements have been made in the durability and weather resistance of the thin films deposited on the lens surfaces by this process. Lenses coated with these improved methods require no more careful handling than any good lens is entitled to, and fingerprints and dust can be removed without detrimental effects to the coating. The thin films can not be scratched with anything less hard than a metal point. By this process reflectivity can be reduced from 5 per cent for untreated polished surfaces to as low as 0.5 per cent for treated ones. Experiments show that even greater reductions are possible and should be available in the near future.

**New and Old Aspects of the Origins of 96-Cycle Distortion;** J. O. Baker, *RCA Manufacturing Co., Camden, N. J.*, and R. O. Drew, *Indianapolis, Ind.*

The work of previous investigations is reviewed and correlated with the results obtained in a comprehensive study of 96-cycle distortion due to the presence of sprocket-holes adjacent to the sound-track.

This distortion has been known for some time. Much improvement has been made by the adoption of the magnetic-drive recorder, the non-slip printer, and the rotary stabilizer sound-head for the purpose of overcoming the problem of slippage.

Recording of sound on doubly perforated film will introduce 96-cycle disturbances of both amplitude and frequency modulation because of the film flexure and possible variations of film speed at the sprocket-hole rate.

Processing of sound records on doubly perforated film will introduce a 96-cycle hum and amplitude modulation depending upon the processing technic.

Printing of sound records on doubly perforated film introduces 96-cycle hum and disturbances of both amplitude and frequency modulation, due to film flexure and variations of film speed at sprocket-hole rate.

Reproducing of sound records on doubly perforated film introduces 96-cycle disturbances because of film flexure.

The use of doubly perforated film for any one of the four steps of recording, printing, processing, or reproducing will result in a 96-cycle disturbance of the reproduced sound.

Since it has been proved that the presence of the sprocket-holes adjacent to the sound-track is the source of all 96-cycle distortion, and the omission of the sprocket-holes entirely eliminates this distortion, it becomes obvious that singly



perforated film should be used throughout all phases of sound recording and reproduction if complete freedom from 96-cycle distortion is to be obtained.

A substantial improvement can be realized if the singly perforated film is employed only for the original negative, master positive, and re-recorded negative, and doubly perforated film for the release prints.

The use of singly perforated film throughout all phases has a decided advantage of providing additional space, without affecting the picture dimensions for a double-width sound-track or two sound-tracks, one for control or other purposes.

**An All-Purpose Sound-Track Printer;** G. M. Best, *Warner Brothers-First National Studios*, Burbank, Calif.

When Warner Bros. Studio changed the type of recording from variable-density to ultraviolet variable-area several years ago, existing printers were unable to handle more than one type of printing on a production basis. Hence, certain printers had to be set aside for variable-density printing only, to take care of the sound-effects library; others for ultraviolet printing only; and one was segregated for white-light and blue-light printing of fine-grain duplicating negatives and positives. As all these printers were from twelve to seventeen years old, they were not capable of producing prints completely free from weave or slippage, so under the supervision of A. J. Tondreau, head of the camera and laboratory repair shop at the Studio, a completely new printer was designed and built to handle all sound-track printing, both for the studio and release printing.

Incorporated in one printing head is a novel, non-slip film movement, a selection of filters for ultraviolet or fine-grain negative printing at the turning of a dial, accurate regulation of light over a scale nearly three times as broad as previous printers, and equipment for variable-density printing. Negative and positive weave is limited to  $\approx 0.001$  inch, the negative setting being adjustable to take care of negative shrinkage. Operating at nearly twice the speed of previous printers, four of the new machines provide adequate service with ten companies shooting and three or more pictures in the dubbing and release stages.

**Some Equipment Problems of the Direct 16-Mm Producer;** Loyd Thompson, *The Calvin Co.*, Kansas City, Mo.

The increased use of direct 16-mm production for industrial and educational use has caused a need for more and better equipment. A great deal of the 16-mm equipment on the open market has been designed for amateur use. Most of this equipment gives perfectly satisfactory service even when used for industrial purposes. However, much of it could be redesigned and built better so that it would stand up under hard use and would also allow the user to work faster and easier. A limited survey was made among the 16-mm film producers to find what was most wanted in 16-mm equipment and film. Some suggestions are made for improvements in film stocks, cameras, and sound-recording and projection equipment. Improvements are also suggested for 16-mm laboratory service.

**Some Recent Advances in the Photographic Process;** C. E. K. Mees, *Eastman Kodak Company*, Rochester, N. Y.

A popular discussion of recent advances in our knowledge of what happens when photographic materials are exposed and developed.

**The Stereophonic Sound-Film System—General Theory;** Harvey Fletcher, *Bell Telephone Laboratories*, New York, N. Y.

The general requirements are discussed for an ideal recording-reproducing system as determined by the characteristics of hearing of a typical group of persons listening in a typical concert hall or theater. Quantitative values are set down as ideal objectives. Although microphones, loud speakers, and amplifiers which had been developed for the stereophonic transmission system were available for meeting these objectives, no recording medium was known which would record the wide dynamic range of intensity levels which the objectives indicated was necessary. However, this wide intensity range objective was met by using a compandor in the electrical system. A general discussion is given of the reasons for choosing the particular compandor used, for using variable-area rather than variable-density on the recorded film, for using three instead of a greater or lesser number of channels. A general description of the stereophonic sound-film system is given, including the enhancement feature. This feature makes it possible to re-record from the original recording, at the same time making any desirable changes in the dynamic range or frequency response in each of the three channels.

**Mechanical and Optical Equipment for the Stereophonic Sound-Film System;** E. C. Wente, R. Biddulph, L. A. Elmer, and A. B. Anderson, *Bell Telephone Laboratories*, New York, N. Y.

The same mechanism is employed for propelling the film in both recording and reproducing. To permit recording of the longer orchestral selections without interruption, the machines are designed to handle film in 2000-ft lengths. Special features of the film-propulsion system for obtaining great uniformity of speed at the translation points are described. The three signal and one control-channel currents are recorded by means of light-valves of identical construction. All four tracks are exposed while the film is passing over a free-running supporting roller, mounted on the same shaft with a new type of internally damped impedance roller. In reproduction, each track is exposed through an objective of high aperture to light from an incandescent source. After passing through the film, the light from each track is carried by a glass rod to a photoelectric cell.

**The Stereophonic Sound-Film System—Pre- and Post-Equalization of Compandor Systems;** J. C. Steinberg, *Bell Telephone Laboratories*, New York, N. Y.

In order best to fit the volume range of the program material into the volume range available in sound-film, it is generally advantageous to pre-equalize the program material before recording, and to compensate for the equalization by means of a complementary post-equalizer on reproduction. The type and amount of pre-equalization depends upon the properties of hearing and on the characteristics of the program material and the film noise. This paper discusses the relations between these quantities for systems using compandors, where the film noise varies up and down in level as the compandor gains vary. Ideally, different types of pre-equalization are needed for different types of program material, and a compromise must be made if a single type is to be used. The considerations leading to the choice of the pre-equalization used in the stereophonic recording and reproducing system are discussed.

**Electrical Equipment for the Stereophonic Sound-Film System;** W. B. Snow and A. R. Soffel, *Bell Telephone Laboratories*, New York, N. Y.

An electrical system is described which permits the use of sound-film, with its limited signal-to-noise ratio, as a recording medium for wide-range stereophonic reproduction of symphonic music. Noise reduction is accomplished both by pre-equalization, rising to 18 db above 8000 cycles, and by automatic signal compression and expansion of 30 db.

To secure maximum suppression of noise and freedom from distortion, a pilot-operated, flat-top compandor system was selected. In each channel low-level signals are recorded on a separate track with constant gain 30 db above normal, which places them above the film noise. Higher-level signals cause automatic gain reductions and are recorded at substantially full modulation. These signals vary the intensity of a pilot tone, which in turn controls the compressor gain. There is a pilot frequency for each of the three channels, and the three are combined and recorded together on the fourth film-track. During reproduction they are separated by filters, and operate expandors which restore the signals to their original forms but reduce the noise to inaudible levels.

The compressor and expander gains are made proportional to pilot level in db, and the expander range over which this relation holds is 45 db. Therefore a 15-db variation in average pilot level during reproduction causes a corresponding average level change but no distortion. This is used to allow expansion of the original signal intensity range during recording or re-recording by simple gain controls in the pilot circuits.

The paper describes the apparatus and circuits developed to accomplish these results, and discusses the frequency, load, distortion, noise, and dynamic characteristics of both constant and variable-gain elements. Also included are considerations of microphone and loud speaker arrangement and equalization to secure high fidelity of reproduction.

**A Light-Valve for the Stereophonic Sound-Film System;** E. C. Wente, R. Biddulph, *Bell Telephone Laboratories*, New York, N. Y.

This paper describes a light-valve incorporating large electromagnetic damping and operating directly through the ribbon resonance region. Resonance response is only 5 db above low-frequency response and so permits easy equalization. A suitable equalizer provides uniform string displacement per unit driving voltage over the band 30-14,000 cycles with very nearly constant phase-shift per cycle. Problems of structure and size have furnished a mechanical design having several interesting features, among which are mechanical robustness, protection against dirt and moisture, built-in ribbon and optical adjustments, and an optical system integral with the valve structure, thus permitting rapid replacement of valves in the recording machine. This unit has proved a rugged, stable, light-modulator especially free from intermodulation products.

**Internally Damped Rollers;** E. C. Wente and A. H. Müller, *Bell Telephone Laboratories*, New York, N. Y.

Special damping rollers, capable of damping oscillations of rotating shafts without adding a steady load, were first devised by Prof. H. A. Rowland. These rollers had either an annular channel along the periphery filled with a liquid, or a wheel mounted loosely on a shaft co-axially fixed in an outer shell, the interspace



being filled with a liquid. The theory of the action of such rollers in reducing fluctuations in the speed of rotation caused by disturbances from either the load or the driving side is developed and the results are illustrated by graphs. A new form of roller is described in which liquid filling an annular channel within the shell of the roller is coupled to the shell by a mechanical resistance.

**A Non-Cinching Film Rewind Machine;** L. A. Elmer, *Bell Telephone Laboratories*, New York, N. Y.

Cinching, or the sliding between layers of film within a reel, produces scratches and surface abrasions which increase the film noise level. Cinching is more likely to occur in rewinding than anywhere else in the normal usage of sound-film. At the beginning of rewinding, when the supply reel is full and the take-up reel is empty, a small amount of torque is needed for rotating the take-up reel. Under this condition the film will be wound rather loosely. When the supply reel is nearly empty, relatively high film tension is required to produce a given torque on the supply reel. The torque to be applied to the take-up reel will then be high, on account of both the high film tension and the large radius arm of the film spiral on the reel. This high torque is almost certain to cause cinching in the loosely wound bottom portion of the reel. The conditions to be satisfied, if cinching is to be avoided, are analyzed. A power-driven rewind is described which meets these requirements. The film tension is controlled by the weight of the film on the supply reel at all times during the rewind.

**Some Theoretical Considerations in the Design of Sprockets for Continuous Film Movement;** J. S. Chandler, *Eastman Kodak Co.*, Rochester, N. Y.

After a brief introduction into the subject, the paper gives a discussion of the steps of sprocket design with the ultimate aim of keeping the flutter to a minimum.

First the selection of the proper sprocket-tooth pitch is considered, then the steps required in arriving at the proper basic tooth profile and finally the modified tooth profile are illustrated by an example.

Curves of theoretical flutter *versus* per cent of film shrinkage are given for several cases for a 24-tooth sprocket. The effect of number of teeth is also shown by curves.

An analysis of film and friction forces gives a clue to proper film guide design.

A word about sprocket-tooth shapers and results obtained from an experimental sprocket conclude the paper.

The degree of accuracy and the directness of the method, as well as the resulting optimum performance, are noteworthy.

**The Subjective Sharpness of Simulated Television Images;** M. W. Baldwin, Jr., *Bell Telephone Laboratories*, New York, N. Y.

Small-size motion pictures, projected out of focus in simulation of the images reproduced by home television receivers, are used in a statistical study of the appreciation of sharpness. Sharpness, in the subjective sense, is found to increase more and more slowly as the physical resolution of the image is increased. Images of present television grade are shown to be within a region of diminishing return with respect to resolution. Equality of horizontal and vertical resolutions is



found to be a very uncritical requirement on the sharpness of an image, especially of a fairly sharp one.

**Development and Current Uses of the Acoustic Envelope;** H. Burris-Meyer, *Stevens Institute of Technology*, Hoboken, N. J.

The acoustic envelope was developed in August of last year for Paul Robeson. Its purpose was to produce on the concert stage a zone in which acoustic conditions would approximate those of a small, highly reverberant studio. Such conditions were considered desirable since in them the artist hears himself easily and makes no unusual effort to project. The lack of such conditions, usually the case in the concert hall, may lead to tension and the technical faults incident thereto.

The technic consists in reproducing in the restricted zone the significant harmonics of the voice or instrument. The area within which the harmonics are audible must be limited since, for concert use, it is generally requisite that the audience hear nothing emanating from an electronic device. The technic has been employed by Mr. Robeson in all his concerts this season, in halls of widely varying acoustic characteristics, accompanied by piano and by full symphony orchestra. It has also been employed experimentally with full orchestra and settings on the stage of the Metropolitan Opera House; for a violin soloist with piano accompaniment; and for choruses of over one hundred voices. It can be used without affecting radio pick-up.

**Notes on the Mechanism of Disk Recording and Playback;** O. Kornei, *The Brush Development Company*, Cleveland, Ohio.

A theory is developed to explain the well-known amplitude losses, in particular of the upper frequency range, occurring in the transcription of lateral-cut sound recordings. These losses may be attributed to two different causes, one based upon the recording, and the other upon the playback process.

The recording loss is due to the effect of the mechanical load imposed by the record material upon the cutting stylus. The influence of this cutting load upon the cutter performance is discussed briefly, the experimental determination of the load is described, and an empirical law for it is established.

The playback, or translation loss, is caused by the elastic deformation of the sound groove under the influence of the static and dynamic pick-up stylus forces. The resulting deviation of the stylus excursion from the actually recorded value is, according to the theory, equal to the difference between the lateral components of the elastic deformations at the convex wall and the concave wall of the record groove and can be calculated. The playback loss may be positive, zero, or even negative, depending upon the conditions. The theory is set forth, its limitations and accuracy are discussed, and experiments for its verification are described. Calculated curves are shown for the translation losses to be expected under various conditions.

Certain general conclusions are derived with a particular view to proposed construction principles for pick-ups with reduced translation loss.

In contradistinction to an ideal pick-up with infinitely small vertical force and stylus impedance, the conditions in a practical pick-up with finite vertical force are found to call for a certain definite stylus mass and a low resonance frequency in order to counteract the playback loss effectively. The necessary stylus mass is

found to increase with the vertical pick-up force and stylus radius and to decrease with the record velocity.

It is shown that in systems with constant record groove velocity, perfect elimination of the translation loss is possible. In other systems, the loss can not be avoided completely but may be reduced, and the absolute level of the high-frequency reproduction may be raised.

**Analytic Treatment of Tracking Error and Notes on Optimal Pick-Up Design;**  
H. G. Baerwald, *Brush Development Co.*, Cleveland, Ohio.

A complete analysis is given of a class of distortions arising in the reproduction of lateral-cut disk recordings. These are due to the varying angular deviation between the direction of the pivotal axis of the pick-up stylus and the groove tangent, commonly referred to as "tracking error."

As long as the overall distortion present in the reproduction is moderate, the system is "almost linear," and it is permissible to superpose the different components of distortion. This permits separate treatment of the tracking error distortions.

In the simple case of a sinusoidal signal, the complete Fourier spectrum of the pick-up signal is obtained. For general signals, an explicit analytical expansion is obtained for the picked-up signal.

The kinematical effect of the tracking error is an alternating advance and delay of the picked-up signal with respect to the recorded one. The harmonic distortions may thus be characterized as side-bands of phase modulation of the signal by itself. Compared with the ordinary type of non-linear distortion as, *e. g.*, met in tubes, which can be correspondingly characterized as amplified auto-modulation, the spectral distribution of the tracking error distortions is different by emphasis on the higher frequency components. For the second-order distortion, which is the prevalent type, this emphasis is proportional to frequency.

The analysis shows that the distortions due to tracking error are considerably greater than commonly assumed, regarding both their absolute and their nuisance value. Some values given in the literature are more than 50 per cent too small, due to the omission of rigorous procedure. The recording characteristic does not affect the relation between ordinary type and tracking distortions. The distortion is given approximately by the weighted tracking error which is inversely proportional to the groove radius, and is referred to the mean groove radius of the record.

The pick-up design should reduce the weighted tracking error as much as possible. The optimal design is uniquely determined as soon as the type of approximation is prescribed. It is argued that the Tschebychew approximation, which is commonly used in the design of electric wave-filters, is also adequate for the present case. For pick-ups without offset angle, only second-order approximation is possible, while with the right value of offset angle, third-order approximation becomes possible. In the first case, sufficiently small values of distortion can barely be obtained with conventional arm lengths, and in order to avoid unnecessary distortions, the pick-up should be carefully mounted to obtain the optimal underhang. With an offset arm, distortion can easily be reduced to negligible magnitude. The right mounting is again fairly critical, while the optimal offset angle is not.

Simple design formulas of immediate applicability are developed covering the whole practical field of record sizes, speeds, and arm lengths, and the effect of deviations from the optimum designs is given. The magnitude of the centripetal effect in offset arms is also investigated.

**Performance of the Visual Mechanism in the Viewing of Motion Pictures;** Brian O'Brien, *Institute of Applied Optics, University of Rochester, Rochester, N. Y.*

The impression gained by an audience in viewing motion pictures depends to a considerable extent upon the performance characteristics of the human eye. The ability of the average observer to distinguish fine detail, small differences in brightness, and small differences in color bears directly upon the standards for prints and projection. These and certain other characteristics of the visual apparatus will be discussed with particular reference to the viewing of motion pictures.

**The Projection Room—Its Location and Contents;** J. R. Prater, *Congress Theater, Palouse, Wash.*

The location of the projection room should be governed by the following factors: (1) Effect on screen image of (a) Projection angle, (b) Projection distance, (c) Light-beam clearance; (2) Accessibility; (3) Fire Hazard; (4) Heating and ventilating; (5) Plumbing; (6) Noise isolation; (7) Additional space immediately adjoining.

The contents of any projection room should be limited strictly to that which is necessary to carry on the performance with safety, dependability, and excellence. Minimum requirements for projection rooms are discussed.

**Projection Room Equipment Requirements;** J. J. Sefing, *National Theater Supply Co., New York, N. Y.*

Modern projection rooms should be planned to accommodate the needs and requirements of up-to-date sound and motion picture equipment. The convenience and safety of the projectionists and the public should be considered at all times. The equipment should be selected and installed that will be best suited for the needs of the theater. The lamp houses, projector bases, mechanisms, magazines, take-ups, and miscellaneous accessories should be up-to-date and efficient in order to produce a trouble-free sound and picture presentation. The projection room, rewind, motor-generator, and toilet rooms should be designed for practicability, fire-retardation, and noise absorption. The projection room layout should receive the complete approval of all Local, City, or State departments having jurisdiction before completion, and all necessary precautions should be taken to reduce hazards to a minimum. When in doubt as to specific requirements and regulations governing projection room layouts, reliable information should be obtained from sources that are thoroughly familiar with the needs of modern projection. The Society of Motion Picture Engineers' specifications cover in detail the important and desirable features required in ideal projection room layouts.



## SOCIETY ANNOUNCEMENTS

### PROPOSED AMENDMENTS TO THE BY-LAWS

At the meeting of the Board of Governors on January 24, 1941, the following amendments to the By-Laws of the Society were proposed, and approved for publication in the JOURNAL and presentation to the members of the Society at the Business Meeting to be held during the Convention at Rochester, N. Y., on Tuesday, May 6th:

#### *By-Law IV, Sec. 4(b)*

To the list of standing committees of the Society appointed by the Engineering Vice-President, should be added the committees known as the "Process Photography Committee" and "Committee on Preservation of Film."

#### *By-Law VII, Sec. 1(a)*

##### *(Third Paragraph)*

*Present Wording.*—The Secretary shall then notify these candidates of their nomination in order of nominations and request their consent to run for office.

*Proposed Wording.*—The Secretary shall then notify these candidates of their nomination.

#### *By-Law XI, Sec. 6*

##### *(Last Paragraph)*

*Present Wording.*—The remainder of the procedure shall be in accordance with the procedure specified for the election of Officers of the General Society as described in By-Law VII, Section 1(a), the word "*Manager*" being substituted for the word "*Governor*."

*Proposed Wording.*—The Chairman of the Section shall then notify these candidates of their nomination. From the list of acceptances not more than two names for each vacancy shall be selected by the Board of Managers and placed on a letter ballot. A blank space shall be provided on this letter ballot under each office, in which space the names of any Active, Fellow, or Honorary members other than those suggested by the Board of Managers may be voted for. The balloting shall then take place.

The ballot shall be enclosed in a blank envelope which is enclosed in an outer envelope bearing the local Secretary-Treasurer's address and a space for the member's name and address. One of these shall be mailed to each Active, Fellow, and Honorary member of the Society, residing in the geographical area covered by the Section, not less than forty days in advance of the annual Fall Convention.

The voter shall then indicate on the ballot one choice for each office, seal the ballot in the blank envelope, place this in the envelope addressed to the Secretary-Treasurer, sign his name and address on the letter, and mail it in accordance with



the instructions printed on the ballot. No marks of any kind except those above prescribed shall be placed upon the ballots or envelopes.

The sealed envelopes shall be delivered by the Secretary-Treasurer to his Board of Managers at a duly called meeting. The Board of Managers shall then examine the returned envelopes, open and count the ballots, and announce the results of the election.

The newly elected Officers and Managers shall take office on the January 1st following their election.

### JOURNAL AWARD AND PROGRESS MEDAL

The following regulations pertaining to the Journal Award and the Progress Medal of the Society of Motion Picture Engineers are published in accordance with the provisions for such publication contained therein. Members of the Society who wish to nominate recipients for either or both the Awards should communicate their nominations to the General Office of the Society as promptly as possible.

#### JOURNAL AWARD

The Journal Award Committee shall consist of five Fellows or Active members of the Society appointed by the President and confirmed by the Board of Governors. The Chairman of the Committee shall be designated by the President.

An appropriate certificate shall be presented at the Fall Convention of the Society to the author or to each of the authors, as the case may be, of the most outstanding paper which is originally published in the JOURNAL of the Society during the preceding calendar year.

A list of five other papers may also be recommended for honorable mention by the Committee.

A majority vote of the entire Committee shall be required for the election to the Award. Absent members may vote in writing.

The Committee shall be required to make its report to the Board of Governors for ratification at least one month prior to the Fall Meeting of the Society.

These regulations, a list of the names of those who have received the Journal Award, the year of each award, and the titles of the papers shall be published annually in the JOURNAL of the Society.

The Journal Award Committee for the current year is as follows:

R. E. FARNHAM, *Chairman*

J. A. DUBRAY

A. M. GUNDELFINGER

O. SANDVIK

T. E. SHEA

The Awards in previous years have been as follows:

1934—Peter Andrew Snell, for his paper entitled "An Introduction to the Experimental Study of Visual Fatigue." (*Published May, 1933*)

1935—Lloyd Ancile Jones and Julian Hale Webb, for their paper entitled "Reciprocity Law Failure in Photographic Exposure." (*Published September, 1934*)

1936—E. W. Kellogg, for his paper entitled "A Comparison of Variable-Density and Variable-Width Systems." (*Published September, 1935*)

1937—D. B. Judd, for his paper entitled "Color Blindness and Anomalies of Vision." (*Published June, 1936*)

1938—K. S. Gibson, for his paper entitled "The Analysis and Specification of Color." (*Published April, 1937*)

1939—Herbert T. Kalmus, for his paper entitled "Technicolor Adventures in Cinemaland." (*Published December, 1938*)

1940—Robert R. McMath, for his paper entitled "The Surface of the Nearest Star." (*Published March, 1939*)

#### PROGRESS MEDAL

The Progress Award Committee shall consist of five Fellows or Active members of the Society, appointed by the President and confirmed by the Board of Governors. The Chairman of the Committee shall be designated by the President.

The Progress Medal shall be awarded each year to an individual in recognition of any invention, research, or development which in the opinion of the Committee, shall have resulted in a significant advance in the development of motion picture technology.

Any member of the Society of Motion Picture Engineers may recommend persons deemed worthy of the award. The recommendation in each case shall be in writing and in detail as to the accomplishments which are thought to justify consideration. The recommendation shall be seconded in writing by any two Fellows or Active members of the Society, who shall set forth their knowledge of the accomplishments of the candidate which, in their opinion, justify consideration.

The Committee shall meet during the month of June. Notice of the meeting of the Committee held for the purpose of considering the award of the Progress Medal shall appear in the June issue of the JOURNAL. All proposals shall reach the Chairman not later than May 20th.

A majority vote of the entire Committee shall be required to constitute an award of the Progress Medal. Absent members may vote in writing.

The report of the Committee shall be presented to the Board of Governors for ratification at least one month before the Fall Meeting of the Society.

The recipient of the Progress Medal shall be asked to present a photograph of himself to the Society, and, at the discretion of the Committee, may be asked to prepare a paper for publication in the JOURNAL of the Society.

The regulations, a list of the names of those who have received the medal, the year of each award, and a statement of the reason for the awards shall be published annually in the JOURNAL of the Society.

The Progress Medal Award Committee for the current year is as follows:

K. F. MORGAN, *Chairman*

E. W. KELLOGG

E. C. RICHARDSON

P. J. LARSEN

E. C. WENTE

The Awards in previous years have been as follows:

1935—Edward Christopher Wente, for his work in the field of sound recording and reproduction. (*Cf. issue of December, 1935*)

1936—Charles Edward Kenneth Mees for his work in photography. (*Cf. issue of December, 1936*)

1937—Edward Washburn Kellogg for his work in the field of sound reproduction. (*Cf. issue of December, 1937*)

1938—Herbert Thomas Kalmus for his work in color motion pictures. (*Cf. issue of December, 1938*)

1939—Lloyd A. Jones for his scientific researches in the field of photography. (*Cf. issue of December, 1939*)

1940—Walt Disney for his contributions to the technology of motion picture cartoon production. (*Cf. issue of December, 1940*)

### ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee the following applicants for membership were admitted into the society in the Associate Grade:

- |   |   |
|---|---|
| BACK, L. B.<br>Capitol Theater Bldg.,<br>Baltimore, Md.             | GREENE, W. R.<br>2238 N. Canyon Drive,<br>Hollywood, Calif.                                 |
| BARDWELL, A. N.<br>626 N. Commonwealth Ave.,<br>Los Angeles, Calif. | GUNBY, O. B.<br>RCA Manufacturing Company,<br>501 N. LaSalle St.,<br>Indianapolis, Ind.     |
| BECKER, L. S.<br>3495 La Sombra Drive,<br>Hollywood, Calif.         | HAUGE, C. W.<br>Wheelan Studios,<br>370 Seventh Ave.,<br>New York, N. Y.                    |
| BENJAMIN, G. H.<br>11251 Graham Pl.,<br>W. Los Angeles, Calif.      | JONES, R.<br>152 Edward St.,<br>Brisbane, B. 15,<br>Queensland, Australia                   |
| BROWN, H. J.<br>420 Robin Rd.,<br>Allentown, Pa.                    | LOWE, H. D.<br>Electrical Research Products, Inc.<br>6601 Romaine St.,<br>Hollywood, Calif. |
| CULLEY, R.<br>9829 Lake Ave.,<br>Cleveland, Ohio                    | MARCATO, R. C.<br>227 Thrasher St.,<br>Montgomery, Ala.                                     |
| DOOLITTLE, E. J.<br>5725 Ridgedale Rd.,<br>Baltimore, Md.           | MASTERS, W. N., JR.<br>Box 2141,<br>Hollywood Station,<br>Los Angeles, Calif.               |
| ENGLE, P. R.<br>3523 Adams Ave.,<br>Des Moines, Ia.                 | McTEAR, J. P.<br>1706 S. Sycamore Ave.,<br>Los Angeles, Calif.                              |
| FORREST, J. L.<br>29 Charles St.,<br>Binghamton, N. Y.              |   |
| GAMBET, E.<br>3221 Clark Ave.,<br>Burbank, Calif.                   |   |

MISHARA, M. M.  
98 Beltran St.,  
Malden, Mass.

PEW, J. E.  
2033 Camden Ave.,  
W. Los Angeles, Calif.

POPE, J.  
7342 Jeffery St.,  
Chicago, Ill.

SPICER, E. E.  
RCA Manufacturing Company,  
1016 N. Sycamore Ave.,  
Hollywood, Calif.

TONDREAU, A. W.  
7871 Hillside Ave.,  
Hollywood, Calif.

WILSON, F. R.  
10519 Valley Spring Lane,  
N. Hollywood, Calif.

In addition, the following applicants have been admitted to the Active Grade:

CHAPMAN, J. P. J.  
The Huon,  
Branksome Hill Rd.,  
Bournemouth, England

FESSLER, F. D.  
16 Abrams Pl.,  
Lynnbrook, L. I., N. Y.

LOOFBOUROW, J. R.  
4038 Clifton Ave.,  
Cincinnati, Ohio

LYMAN, D. F.  
Eastman Kodak Co.,  
343 State St.,  
Rochester, N. Y.

MELICK, A. L.  
RCA Manufacturing Co.,  
1016 N. Sycamore Ave.,  
Los Angeles, Calif.

POWERS, D. B.  
1359 Hill Drive,  
Eagle Rock, Calif.

SUKHUM, P.  
Pridi Productions,  
1021 Silom Rd.,  
Bangkok, Thailand



# JOURNAL

## OF THE SOCIETY OF

# MOTION PICTURE ENGINEERS

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June, 1941

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# JOURNAL

## OF THE SOCIETY OF

### MOTION PICTURE ENGINEERS

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**\*Term expires** December 31, 1941.

**\*\*Term expires** December 31, 1942.

## ACOUSTIC DESIGN FEATURES OF STUDIO STAGES, MONITOR ROOMS, AND REVIEW ROOMS\*

D. P. LOYE\*\*

*Summary.*—A survey was made of studio experience, and measurements were made of stages, review rooms, and other units. These data were correlated and used as a valuable guide in the determination of the optimum characteristics and dimensions recommended for major studio scoring stages, monitor rooms, dubbing rooms, review rooms, and studio theaters.

*Information regarding Hollywood preview theaters is included in an Appendix.*

In designing a new studio, or units of an existing studio, it is desirable to have in mind the ideal requirements. "Hitch your wagon to a star," said Emerson in speaking of ideals which should govern our actions. It is evident that in many cases it is impracticable to build according to the ideal design, but it is well to evaluate the ideal characteristics and incorporate as many of them into the studio unit as is feasible.

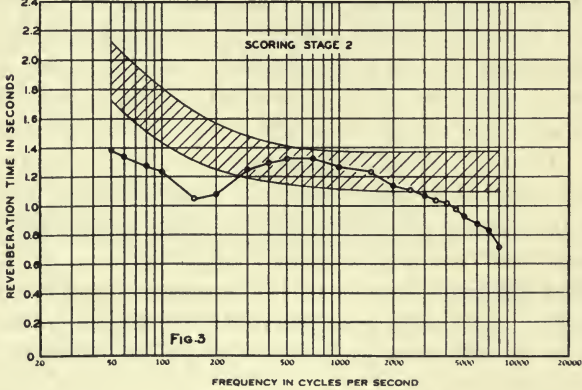
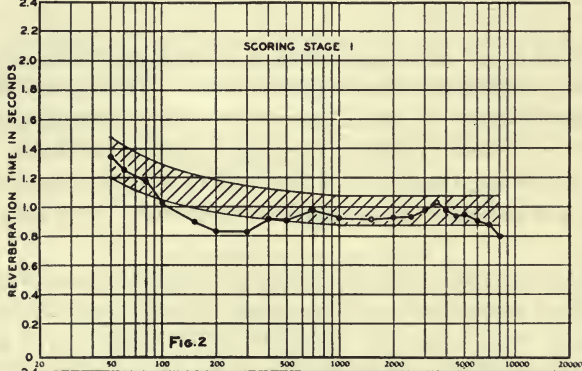
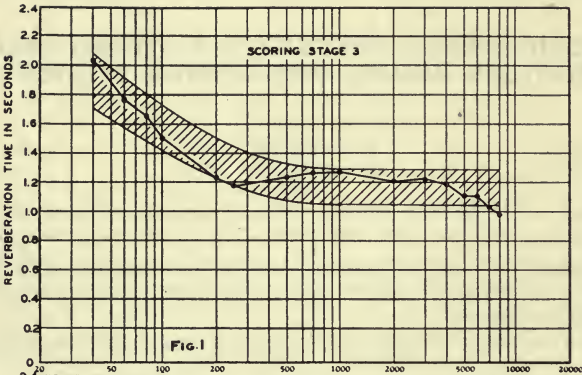
The ideal scoring stage should be just the right size to accommodate the number of musicians to be recorded; should have the optimum reverberation time frequency characteristic; should have adequate insulation to exclude all noises and should conform to other optimum requirements involving shape, splaying of the walls, distribution of acoustical material, *etc.* The ideal scoring monitor room, in which the mixer hears the music as it is recorded, should be the size of the average theater, and should have the optimum reverberation characteristic. The mixer should also be provided with keys for increasing the high and low-frequency response characteristics above those required in the average theater, in order to make it possible for him to listen critically and readily detect recording faults.

In the ideal dubbing room, in which the sound is finally re-recorded for the finished picture, it is essential that the mixer be able to hear the sound as it will later be reproduced in the average theater.

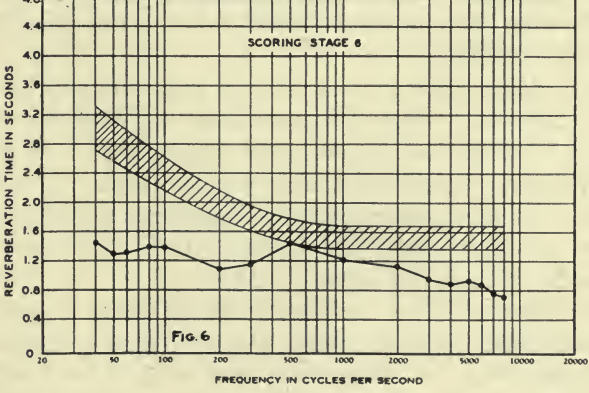
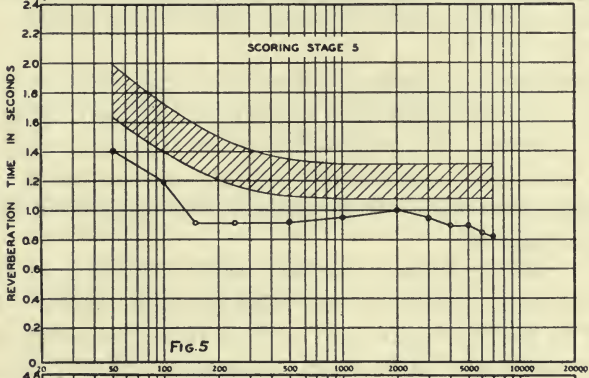
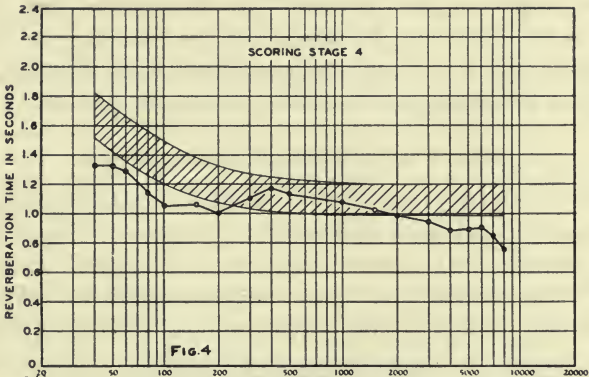
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\* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received February 26, 1941.

\*\* Electrical Research Products, Inc., Hollywood, Calif.







Therefore, he requires an average size theater with optimum characteristics. He requires also facilities for increasing the low and high-frequency response characteristics for critical listening purposes. Under ideal conditions, the studio review rooms and the studio theater should also be average theater size and have the characteristics described for the scoring monitor room and dubbing room.

#### STUDIO EXPERIENCE AND REQUIREMENTS

It is obviously impracticable to provide ideal conditions for all studio rooms. Instead of an assortment of scoring stages of various sizes to accommodate various numbers of musicians, they must of necessity be limited to one or two stages per studio. The scoring monitor room, dubbing room, review rooms, and studio theater can not all be made the size of the average theater. The question then arises, what are the practical compromises in the design of the essential studio units?

In determining the answer to these questions, studio experience is valuable. "Ask the Man Who Owns One," is good advice in more than one instance. To obtain this information a survey of sound directors, and other competent sound personnel in the major Hollywood studios, was made. The answers to the questions asked them are described herein.

Tables I to VI, inclusive, contain details regarding opinions concerning the requirements for the various studio units. These are described in the Appendix, and include the opinions of the studio personnel who were interviewed. Summary Table I includes the main features of these six tables which features are described in the main portion of this paper.

From this table it can be seen that for major studios, two scoring stages are favored. Some who questioned the need of two scoring stages believed that two should be provided only where production might require the simultaneous use of both of them. It was the consensus that the small stage should be capable of accommodating 28 musicians, and the large stage 116 musicians. The sizes of these stages are also given in this summary table.

The reverberation time frequency characteristic should conform to well established optimum values which have been agreed upon by various authorities.<sup>1,2,3</sup> These optimum value shave been in force without change during more than ten years. It is also important that the reverberation time frequency characteristics be smooth and with-

out resonance peaks such as often occur in poorly designed stages. Other requirements for a good stage, which have been discussed in a previous publication by the author,<sup>4</sup> and a more recent publication by Messrs. C. C. Potwin and J. P. Maxfield,<sup>5</sup> are as follows:

(1) The walls, floor, and ceiling surfaces should be non-parallel. This is essential in order to avoid sustained cross reflections between parallel surfaces.

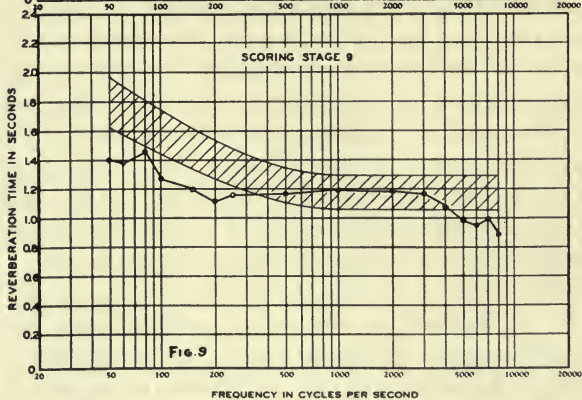
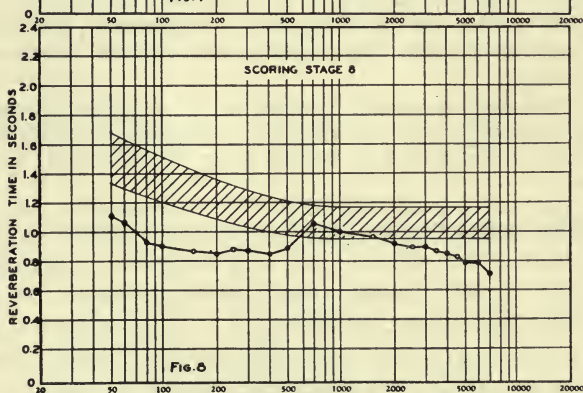
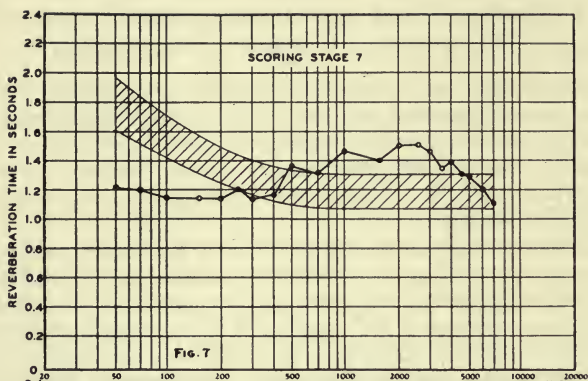
(2) The wall and ceiling surfaces should be angled, convexly curved, or otherwise irregularly broken in order to diffuse the sound. Large, flat, hard surfaces from which there might be prominent first-reflections into the recording microphone, should be avoided.

(3) The acoustic treatment should be scattered, with some acoustic absorbing material in the "live end," and some reflecting material in the "dead end" of the stage. It should be distributed in such a manner that there is slightly less absorbing material in the end of the stage in which the sound is produced than in the microphone end. In this design, convex rather than concave curvatures should be used in order to avoid sound concentrations, and regular breaking up of the wall and ceiling surfaces that might result in acoustic defraction patterns should be avoided.

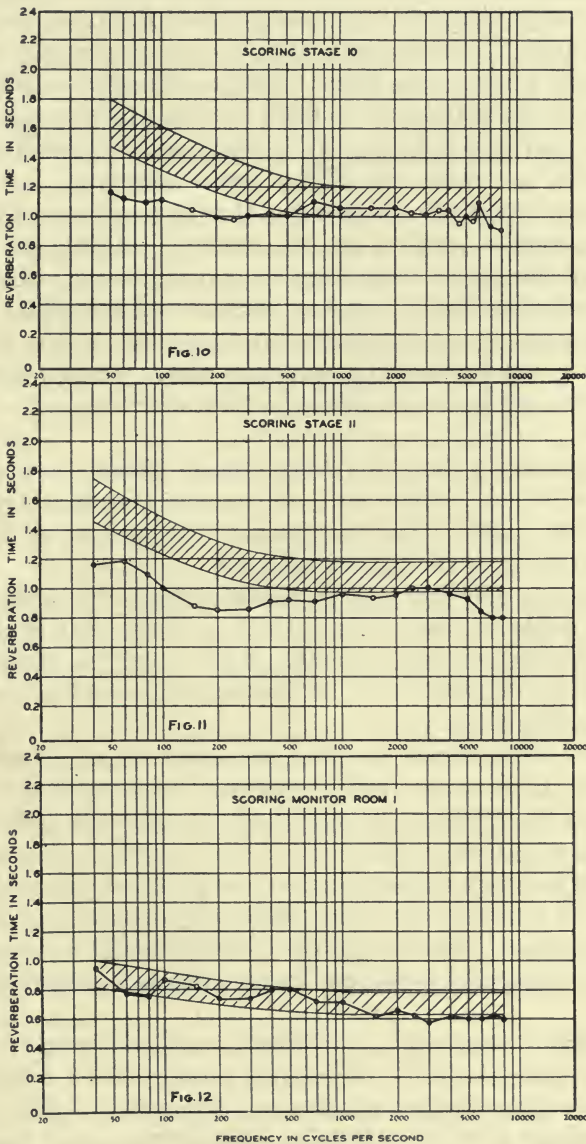
(4) The stage insulation should be adequate to exclude outside noises. The maximum permissible noise level is generally considered to be 30 db above  $10^{-16}$  watts per sq-cm as measured with a sound meter having a 40-db ear-weighting characteristic.

The scoring monitor room should be review room size, and according to the consensus should have a reverberation time frequency characteristic slightly deader than theater optimum, in order to provide critical listening conditions. It is evident from a reference to Table II of the Appendix, that the votes are rather close on this question, seven voting for a room with theater optimum reverberation characteristic and nine voting for a slightly deader monitor room. It is probable that with keys for extending the monitor room response both up and down in the frequency scale above that required for theater listening, critical listening conditions could thereby be provided that would make it unnecessary for the scoring monitor room reverberation to be below theater optimum. This undoubtedly would be true for rooms having scattered acoustic treatment designed in accordance with the most recent acoustic developments.

The dubbing room is important because here the sound is finally re-recorded. It is therefore desirable that this room be made as nearly like the average optimum theater as practicable. Where a studio theater is available, a very good dubbing arrangement is to use it for such purposes. Scoring stages also have been adapted to advantage for dubbing purposes. According to Summary Table I,







the opinions expressed by studio representatives were that the studio theater should be used for dubbing where feasible. When a studio theater, scoring stage, or the equivalent is not available, the dubbing room should be the same size as the review room, in order to standardize studio listening conditions. The reverberation time frequency characteristic should conform to theater optimum requirements.

Studio experience indicates that a desirable review room size is 54 feet long, 32 feet wide, and 20 feet high. This is the average size voted for by the studio personnel. If it is necessary to make the rooms appreciably smaller, special precautions should be taken to avoid room resonance effects by splaying the walls and ceiling and by properly selecting and distributing the acoustic materials. The reverberation time frequency characteristic should conform to theater optimum as is indicated in the summary table. Other requirements for a good review room are similar to those stated above for the scoring stage.

The consensus is that the studio theater should have a seating capacity of 462, the opinions as to the number of seats required ranging from 225 to 800. The reverberation time frequency characteristic should, of course, be theater optimum.

Inasmuch as only one theater would normally be considered per studio, it would not be unreasonable to presume that in the larger studios, the theater should be the ideal size. The question then arises, what is the ideal size? At the outset it should be stated that it can be made too big.

The ideal studio theater size is equal to that of the average theater from which the greatest box-office returns are obtained. The *Motion Picture Herald* (May 28, 1938) states that the bulk of the revenue comes from theaters in cities of more than 50,000 persons, where 45 per cent of the seating capacity is concentrated, and where admissions charged are relatively high. In these cities, the total number of seats is given as 4,952,313, and the total number of theaters is 4939. The average number of seats per theater, therefore, is almost exactly 1000.

An article by Messrs. C. C. Potwin and B. Schlanger<sup>6</sup> indicates that the average theater of this seating capacity has a volume of approximately 150 cubic-feet per person. From this it follows that the average theater in the United States from which most of the revenue is obtained has a volume of 150,000 cubic-feet, and a seating capacity of 1000 persons.

It will be realized that studios, in the design of their theater, would not necessarily wish to crowd in as many seats as the theater owner would desire to have. Therefore, the studio theater having the optimum capacity of 150,000 cubic-feet might be provided with only seven or eight hundred *de luxe* seats, with more than the usual space between rows. The space required for the dubbing mixer's desk and controls also would reduce the seating capacity of the studio theater.

#### PRESENT STUDIO CONDITIONS

An important step of this studio study was measuring the reverberation time frequency characteristics of major Hollywood studio units, and relating opinions regarding them to the characteristics obtained. Scoring stages, a scoring monitor room, dubbing rooms, review rooms, and Hollywood preview theaters were measured. The results obtained will now be described in greater detail.

*Scoring Stages.*—The first eleven figures represent Hollywood scoring stages. In each case the solid line represents the measured characteristic, and the cross-lined band represents the desirable or optimum characteristic limits.

Stage 3 (Fig. 1) is a scoring stage having a characteristic which conforms closely to the optimum requirements. This stage has been giving very good results since it was redesigned in accordance with the requirements described in a preceding section of this paper.

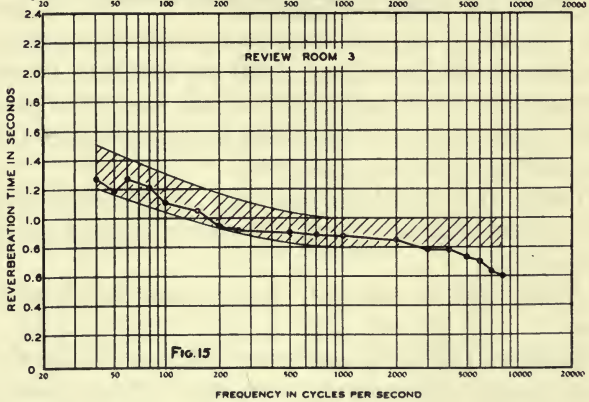
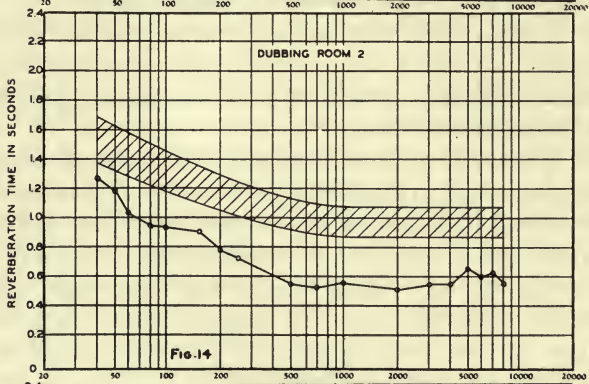
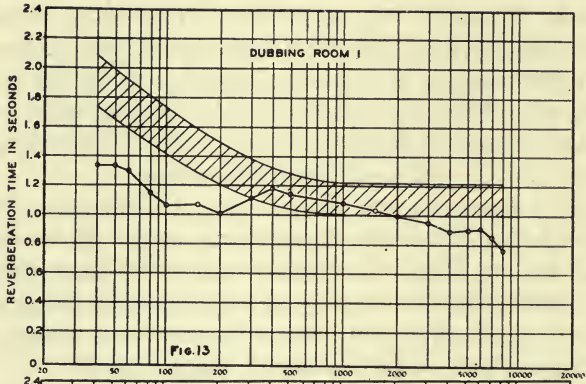
Stage 1 (Fig. 2) has a characteristic which generally conforms to the optimum requirements. This stage, however, is substantially smaller than the small stage specified in Table I, and will not accommodate the required number of musicians.

Stage 2 (Fig. 3) was adapted temporarily on short notice for musical scoring purposes. Had time permitted, it is probable that, by changing the bracing of the stage panels, it would have been possible substantially to reduce the panel resonance effect to which is attributable the dip in the characteristic at 150 cycles.

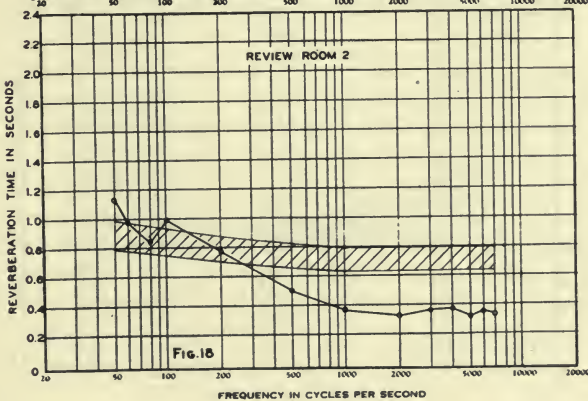
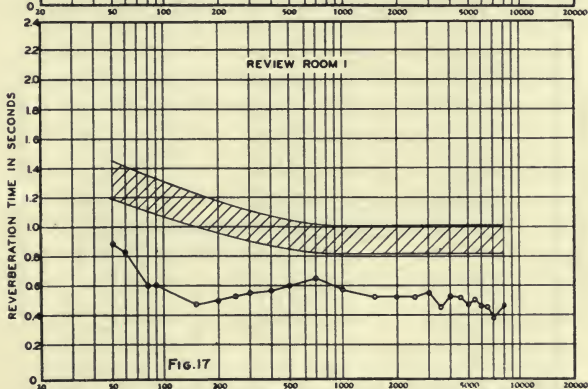
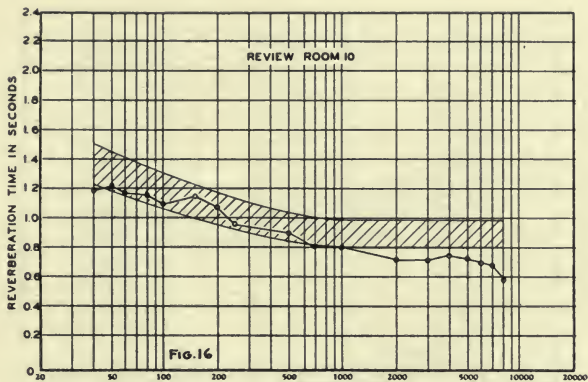
Stage 4 (Fig. 4) is a good scoring stage, but it could be improved by slightly raising the low and high-frequency ends of the reverberation characteristic.

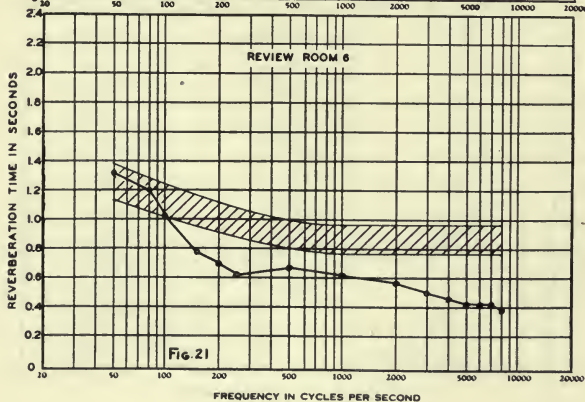
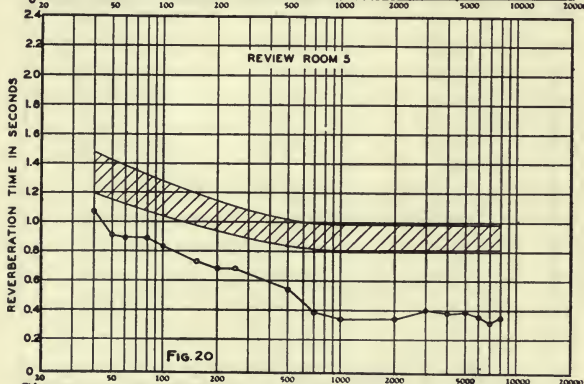
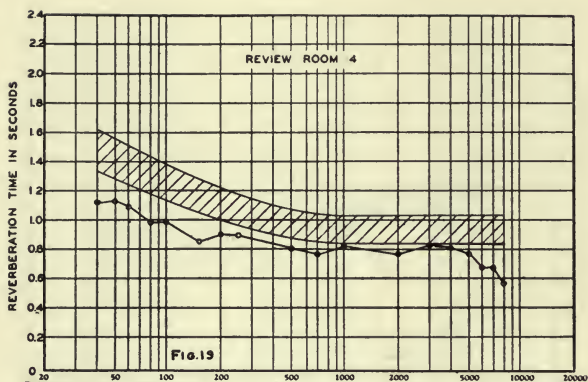
Stage 5 (Fig. 5) has a smooth characteristic but is too dead for best results.

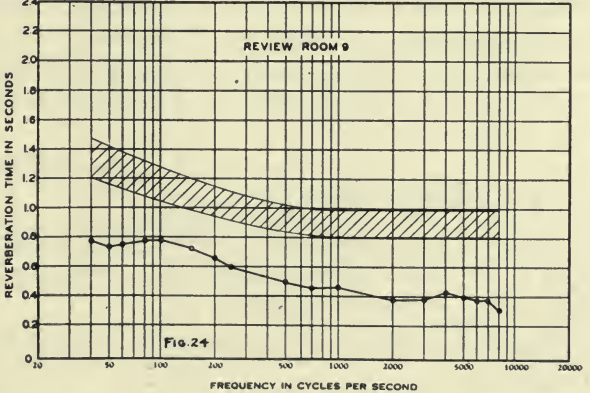
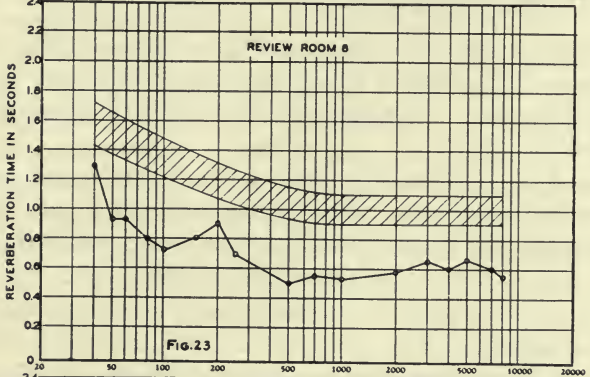
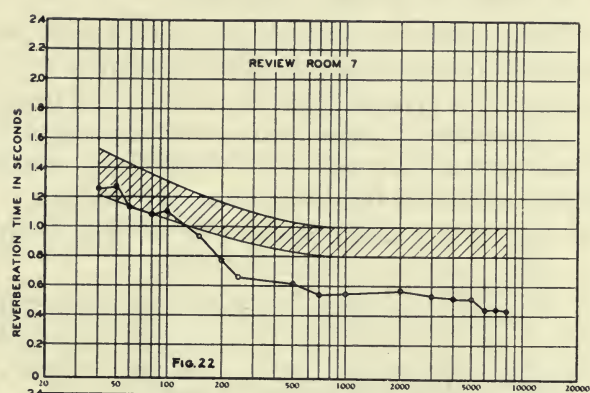
It is to be noted that the characteristic of Stage 6 (Fig. 6) is plotted to a double time-scale in order to accommodate the characteristic of this very large stage. This is one of the largest stages which has been adapted for musical recording purposes.











Stage 7 (Fig. 7) has excessive reverberation in the mid-frequency range and not enough at the low frequencies.

Stage 8 (Fig. 8) contains a 700-cycle peak in the characteristic, and the reverberation is generally somewhat below optimum.

Stage 9 (Fig. 9) is recognized to be a very good scoring stage. However it is the opinion of those who use it that it can be improved by raising the low-frequency end of the reverberation characteristic. The measurements confirm the listening tests in this regard.

Stage 10 (Fig. 10) has been considered to be a good scoring stage by those who have used it for a number of years.

Stage 11 (Fig. 11) is somewhat below the optimum reverberation characteristic requirements, but good results are obtained by locating the recording microphone farther from the orchestra than is normally considered good practice.

*Scoring Monitor Rooms.*—Scoring Monitor Room 1 (Fig. 12) has a reverberation characteristic which conforms very closely to the optimum requirements. It is considered to be a very satisfactory room except that it is small.

*Dubbing Rooms.*—Dubbing Room 1 (Fig. 13) is a scoring stage used for dubbing purposes. It is considered to be a good room, but it is recognized that it can be improved by raising the low and high-frequency ends of the reverberation characteristic.

Dubbing Room 2 (Fig. 14) is substantially below the optimum reverberation requirements.

*Review Rooms.*—The two review rooms having characteristics which most nearly conform to the optimum requirements, are 3 and 10 of Figs. 15 and 16. These characteristics also are smooth as is desirable. These rooms are considered to be among the best in Hollywood.

Room 1 (Fig. 17) has a characteristic which is generally satisfactory in shape, but is recognized as being too dead.

Room 2 (Fig. 18) is too dead at the middle and high frequencies.

Room 4 (Fig. 19) has a smooth characteristic which is generally good in shape, but is somewhat too dead.

Room 5 (Fig. 20) is substantially too dead particularly at the middle and high frequencies.

Room 6 (Fig. 21) is optimum at the lowest frequencies, but is appreciably too dead at the middle and high frequencies.



Room 7 (Fig. 22) is also within the optimum band at the low frequencies, but is appreciably too dead at the middle and high frequencies. It is recognized that this room can be improved by the elimination of cross-reflections between parallel walls, and by increasing the reverberation in the middle and high-frequency range.

Room 8 (Fig. 23) has two prominent peaks in the reverberation characteristic, which make the response of this room not entirely satisfactory. These peaks occur at 40 and 200 cycles. The former affects musical reproduction, and the latter occurs at the fundamental frequency of women's voices.

Room 9 (Fig. 24) has a very smooth characteristic. It has been recognized, however, as being appreciably too dead, and therefore since these measurements, the room has been livened by painting portions of the acoustical plaster with which the room is treated.

The reverberation characteristic of Room 11 (Fig. 25) is unsatisfactory primarily because of the resonance peaks at the low frequencies. Due to a comparatively low and extensive ceiling of hard plaster, sustained reflections occur between the ceiling and floor, which are parallel, resulting in harmonic reinforcements at frequencies at approximately 50, 80, and 150 cycles. Had the reverberation times been measured at 5-cycle intervals, these peaks would have been determined more accurately, and the harmonic relationship between them undoubtedly would have been shown more exactly. Another contributing factor to the excessive low-frequency reverberation, is the character of the acoustic treatment on floor and walls.

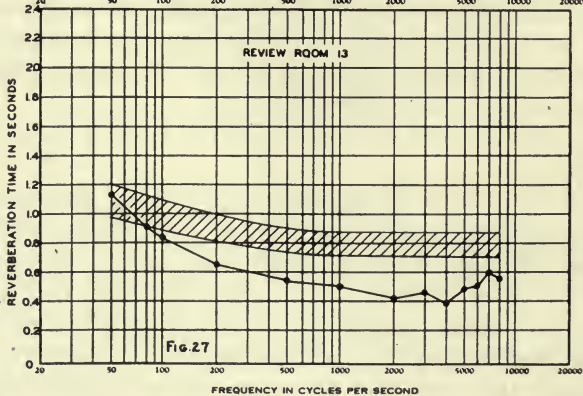
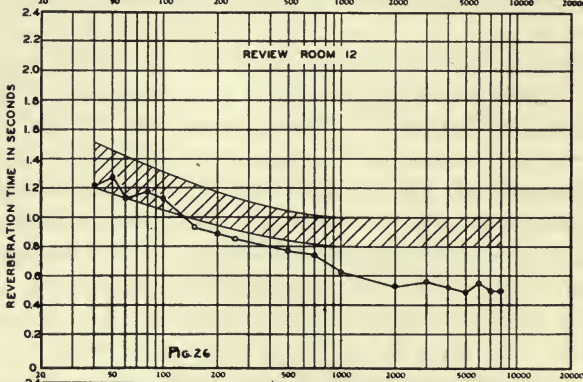
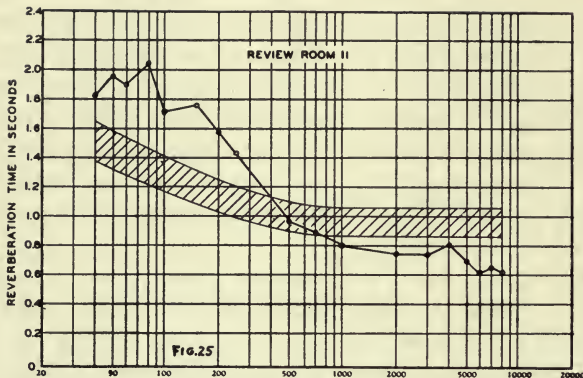
Room 12 (Fig. 26) it is recognized should have the middle and high-frequency reverberation increased. Plans had been initiated to make such changes on the basis of listening tests. The measurements confirmed the judgment of the studio observers.

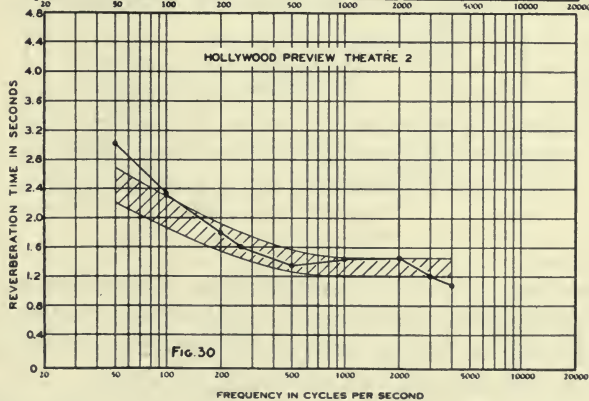
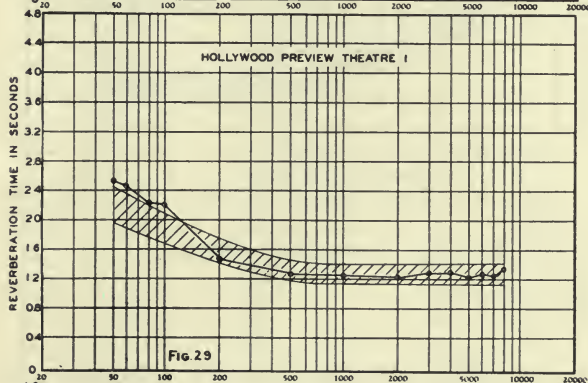
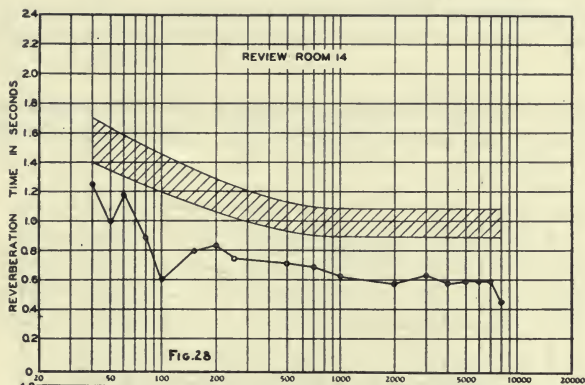
Room 13 (Fig. 27) is a small room having a smooth reverberation characteristic.

Room 14 (Fig. 28) can be improved by increasing the reverberation time, and smoothing the low-frequency end of the characteristic.

*Hollywood Preview Theaters.*—The final figures represent four Hollywood preview theaters. The first and third conform most nearly to the optimum requirements. All, however, are considered to be good theaters, where important pictures are regularly viewed.

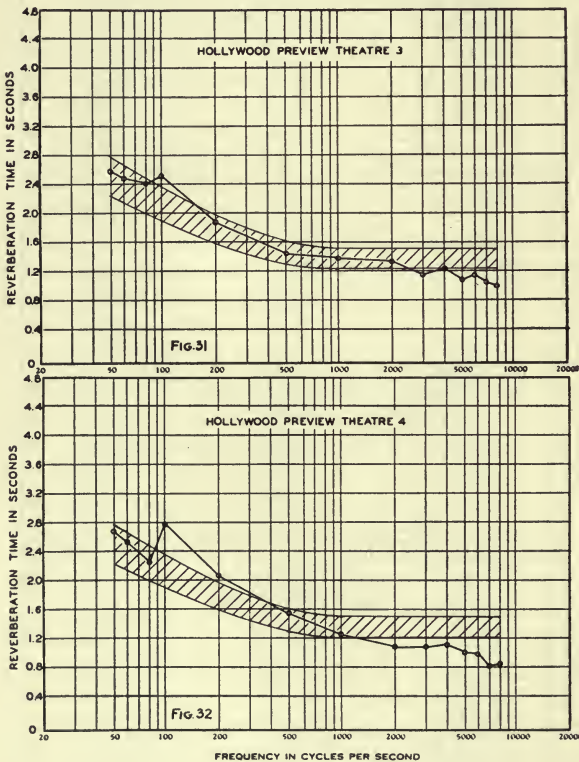
To conclude this portion of the paper, which illustrates conditions existing in major Hollywood studios, the following brief summary table has been prepared.





	Scoring Stages	Review Rooms
Average per cent excessive deadness	11.2	28.6
Average per cent excessive deadness of best stages and rooms	4.1	10.1

It is to be noted that the scoring stages and review rooms considered to be best, are those having reverberation time frequency character-



istics conforming most nearly to optimum requirements. Further details regarding these figures can be obtained from Tables IV and V of the Appendix, as well as from the reverberation time frequency curves, measured and optimum, previously discussed.

In conclusion, the author wishes to thank the studio representatives who assisted in the preparation of this article.



## SUMMARY TABLE I

*Scoring Stages*

Sound Directors and qualified representatives of the sound departments of the major Hollywood studios were interviewed, and their opinions, based upon experience, are here summarized.

Desired Dimensions of Small Stage (Ft)	No. of Musicians	Desired Dimensions of Large Stage (Ft)	No. of Musicians	Comments
73 × 44 × 25	28	137 × 85 × 35	116	Stages considered to be good Stages 3, 4, 9, 10

*Scoring Monitor Rooms*

Desired Size	Desired Reverberation Characteristic
Review room	Deader than theater optimum

*Dubbing Rooms*

Desired Size	Desired Reverberation Characteristic
Studio theater or review room	Theater optimum

*Review Rooms*

Desired Size (Ft)	Desired Reverberation Characteristic	Comments
54 × 32 × 20	Theater optimum	Rooms considered to be good Rooms 3, 4, 10

*Studio Theater*

Desired Seating Capacity	Desired Reverberation Characteristic
462	Theater optimum

## APPENDIX

Tables I to VI, inclusive, contain detailed information regarding the opinions of sound department personnel of major studios as to the desired characteristics and requirements for scoring stages, scoring monitor rooms, dubbing rooms, review rooms, and studio theaters.

Additional data regarding the scoring stages, review rooms, and preview theaters that were measured are also summarized. These data indicate that the reverberation time frequency characteristic of the average scoring stage measured is 11.2 per cent below optimum in the frequency range from 250 to 2000 cycles per second. The four stages considered to be best, however, are only 4.1 per cent below optimum.

The corresponding average characteristic for the Hollywood review rooms measured is 28.6 per cent below optimum. The three best review rooms, however, are only 10.1 below optimum, and the two best review rooms (Rooms 3 and 10) are less than 10 per cent below optimum.

The corresponding average characteristic for the four Hollywood preview theaters, is one-half per cent above optimum in liveness when empty, and 8.2 per cent too dead (according to calculation) with two-thirds audience.

It is assumed that these tables are generally self-explanatory; therefore no detailed descriptions are given. Sound directors and qualified representatives of the Sound Departments of the major Hollywood studios were interviewed, and their opinions, based upon experience, are summarized in Tables I to VI.

TABLE I  
*Scoring Stages*

No. of Stages Required	Desired Dimensions of Small Stage (Ft)	No. of Musicians	Desired Dimensions of Large Stage (Ft)	No. of Musicians
9 favor large and small stages	Maximum 100 × 60 × 30	Maximum 40	Maximum 237 × 140 × 45	Maximum 200
2 favor large and small stages if pro- duction re- quires more than one	Average 73 × 44 × 25  Minimum 60 × 36 × 23	Average 28  Minimum 25	Average 137 × 85 × 35  Minimum 82 × 50 × 28	Average 116  Minimum 70
6 favor one stage				
Orchestra Platform	Type	Comments		
14 favorable	8 favor portable platform	Stages considered to be good Stages 3, 4, 9, 10		
2 believe not essential	3 favor permanent plat- form			

TABLE II  
*Scoring Monitor Rooms*

Desired Size	Desired Reverberation Characteristic
12 favor review room size	7 favor theater optimum
4 favor smaller room as adequate	9 favor deader conditions

*Dubbing Rooms*

Desired Size	Desired Reverberation Characteristic
13 favor same size as review rooms	14 favor theater optimum
2 favor larger size. Where a studio theater is avail- able, it can be made to provide the best dubbing arrangement.	1 favors deader condi- tions

**TABLE III**  
*Review Rooms*

Desired Size	Desired Reverberation Characteristic	Comments
13 favor rooms all the same size having the following dimensions (ft):	11 favor theater optimum	Rooms considered to be too dead
Max. 74 × 45 × 28	1 favors deader conditions	Rooms 1, 9 (Latter room livened recently)
Av. 54 × 32 × 20	5 favor one or more dead rooms and the others theater optimum	Rooms considered to be good
Min. 42 × 25 × 17		Rooms 3, 4, 10
4 favor one or more rooms 70 ft long and the others 50 ft long		

*Studio Theater*

Desired Seating Capacity	Desired Reverberation Characteristic
Max. 800	16 favor theater optimum
Av. 462	
Min. 225	

**TABLE IV**  
*Scoring Stages*

Scoring Stage	Size (Cu-Ft)	Stage Optimum Reverberation Time (Cps)	Stage Optimum Reverberation Time (Sec)	Measured Reverberation Time (Empty)	Reverberation Time in Per Cent below Optimum	Comments
Stage 1 (Fig. 2)	64,000	250	1.07	0.83		
		500	1.02	0.91		
		1000	0.98	0.93		
		2000	0.98	0.93		
		Av.	1.01	0.90	10.9	Small
Stage 2 (Fig. 3)	416,000	250	1.40	1.18		
		500	1.28	1.32		
		1000	1.23	1.27		
		2000	1.23	1.15		
		Av.	1.28	1.23	3.9	
Stage 3 (Fig. 1)	225,000	250	1.31	1.19		
		500	1.20	1.23		
		1000	1.17	1.28		
		2000	1.17	1.21		
		Av.	1.21	1.23	-1.6	Good
Stage 4 (Fig. 4)	124,000	250	1.19	1.07		
		500	1.12	1.14		
		1000	1.09	1.09		
		2000	1.09	1.00		
		Av.	1.12	1.08	3.6	Good

Scoring Stage	Size (Cu-Ft)	Stage Optimum Reverberation Time		Measured Reverbera- tion Time (Empty)	Reverberation Time in Per Cent below Optimum	Comments
Stage 5 (Fig. 5)	245,000	(Cps)	(Sec)			
		250	1.33	0.92		
		500	1.22	0.94		
		1000	1.18	0.95		
		2000	1.18	1.00		
		<hr/>		<hr/>		
		Av.	1.23	0.95	22.7	
Stage 6 (Fig. 6)	2,500,000	250	1.85	1.15		
		500	1.60	1.40		
		1000	1.50	1.22		
		2000	1.50	1.15		
		<hr/>		<hr/>		
		Av.	1.61	1.23	23.5	
Stage 7 (Fig. 7)	220,000	250	1.31	1.20		
		500	1.20	1.37		
		1000	1.17	1.46		
		2000	1.17	1.50		
		<hr/>		<hr/>		
		Av.	1.21	1.38	14.0	
Stage 8 (Fig. 8)	100,000	250	1.17	0.88		
		500	1.10	0.90		
		1000	1.07	1.00		
		2000	1.07	0.94		
		<hr/>		<hr/>		
		Av.	1.10	0.93	15.4	
Stage 9 (Fig. 9)	270,000	250	1.35	1.17		
		500	1.23	1.18		
		1000	1.19	1.20		
		2000	1.19	1.19		
		<hr/>		<hr/>		
		Av.	1.24	1.19	4.0	Good
Stage 10 (Fig. 10)	160,000	250	1.26	0.99		
		500	1.15	1.01		
		1000	1.11	1.07		
		2000	1.11	1.07		
		<hr/>		<hr/>		
		Av.	1.16	1.04	10.3	Good
Stage 11 (Fig. 11)	110,000	250	1.18	0.85		
		500	1.11	0.93		
		1000	1.08	0.97		
		2000	1.08	0.96		
		<hr/>		<hr/>		
		Av.	1.11	0.93	16.2	
Average per cent excessive deadness of above scoring stages					11.2	
Average per cent excessive deadness of four "Good" scoring stages					4.1	



TABLE V  
*Studio Review Rooms*

Review Room	Size (Cu-Ft)	Theater Reverberation Time (Cps)	Optimum Reverberation Time (Sec)	Measured Reverberation Time (Empty)	Reverberation Time in Per Cent Below Optimum	Comments
Room 1 (Fig. 17)	26,000	250	1.02	0.53		
		500	0.94	0.60		
		1000	0.91	0.58		
		2000	0.91	0.52		
		Av.	0.94	0.56	40.4	Dead
Room 2 (Fig. 18)	4,300	250	0.66	0.70		
		500	0.63	0.50		
		1000	0.62	0.37		
		2000	0.62	0.33		
		Av.	0.63	0.48	23.8	
Room 3 (Fig. 15)	25,500	250	1.02	0.92		
		500	0.94	0.90		
		1000	0.91	0.88		
		2000	0.91	0.85		
		Av.	0.94	0.89	5.3	Good
Room 4 (Fig. 19)	33,500	250	1.05	0.89		
		500	0.97	0.80		
		1000	0.94	0.82		
		2000	0.94	0.77		
		Av.	0.97	0.82	15.4	Good
Room 5 (Fig. 20)	22,500	250	1.00	0.68		
		500	0.93	0.54		
		1000	0.90	0.34		
		2000	0.90	0.34		
		Av.	0.93	0.48	48.4	
Room 6 (Fig. 21)	22,000	250	0.99	0.62		
		500	0.92	0.67		
		1000	0.89	0.62		
		2000	0.89	0.56		
		Av.	0.92	0.62	32.6	
Room 7 (Fig. 22)	26,000	250	1.02	0.66		
		500	0.94	0.61		
		1000	0.91	0.54		
		2000	0.91	0.57		
		Av.	0.94	0.60	36.2	

Review Room	Size (Cu-Ft)	Theater Reverberation Time (Cps)	Optimum Reverberation Time (Sec)	Measured Reverberation Time (Empty)	Reverberation Time in Per Cent below Optimum	Comments
Room 8 (Fig. 23)	53,000	250	1.14	0.69		
		500	1.04	0.50		
		1000	1.00	0.53		
		2000	1.00	0.58		
		Av.	1.04	0.58	44.2	
Room 9 (Fig. 24)	22,500	250	1.00	0.60		
		500	0.93	0.50		
		1000	0.90	0.46		
		2000	0.90	0.38		
		Av.	0.93	0.49	47.2	Dead (livened recently)
Room 10 (Fig. 16)	25,700	250	1.02	0.97		
		500	0.94	0.89		
		1000	0.91	0.81		
		2000	0.91	0.72		
		Av.	0.94	0.85	9.6	Good
Room 11 (Fig. 25)	41,300	250	1.10	1.43		
		500	1.01	0.96		
		1000	0.96	0.81		
		2000	0.96	0.75		
		Av.	1.01	0.99	2.0	
Room 12 (Fig. 26)	26,000	250	1.02	0.86		
		500	0.94	0.78		
		1000	0.91	0.63		
		2000	0.91	0.54		
		Av.	0.94	0.71	24.4	
Room 13 (Fig. 27)	10,000	250	0.89	0.63		
		500	0.83	0.54		
		1000	0.81	0.50		
		2000	0.81	0.42		
		Av.	0.83	0.53	36.2	
Room 14 (Fig. 28)	53,000	250	1.14	0.75		
		500	1.04	0.72		
		1000	1.00	0.62		
		2000	1.00	0.58		
		Av.	1.04	0.67	35.6	
Average per cent excessive deadness of above review rooms					28.6	
Average per cent excessive deadness of three "Good" review rooms					10.1	

TABLE VI  
Hollywood Preview Theaters

Polywood Theater							
Theater	Size (Cu-Ft)	Seats	Theater Reverberation Time (Cps)	Optimum Time (Sec)	Measured Reverberation Time (Empty)	Calculated Time $\frac{2}{3}$ Aud.	Reverberation Time in Per Cent below Optimum $\frac{2}{3}$ Aud.
Theater 1 (Fig. 29)	287,000	1500	250	1.50	1.43		
			500	1.32	1.28		
			1000	1.26	1.27		
			2000	1.26	1.24		
			Av.	1.33	1.31	1.20	9.7
Theater 2 (Fig. 30)	500,000	2028	250	1.63	1.60		
			500	1.42	1.34		
			1000	1.35	1.42		
			2000	1.35	1.43		
			Av.	1.44	1.45	1.35	6.2
Theater 3 (Fig. 31)	636,000	2812	250	1.66	1.78		
			500	1.45	1.45		
			1000	1.38	1.40		
			2000	1.38	1.35		
			Av.	1.47	1.50	1.37	6.8
Theater 4 (Fig. 32)	550,000	2756	250	1.64	1.94		
			500	1.43	1.55		
			1000	1.36	1.26		
			2000	1.36	1.08		
			Av.	1.45	1.46	1.30	10.3
Average per cent excessive deadness of above theaters ( $\frac{2}{3}$ audience)							8.2
Average per cent excessive liveness (empty)							0.5

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## DISCUSSION

MR. FRIEDL: What is the "established optimum" reverberation time frequency characteristic referred to?

MR. LOYE: It is the optimum that was recognized for quite a long time in the design of theaters.

MR. FRIEDL: Computed for these individual volumes?

MR. LOYE: Yes.

MR. FRIEDL: Is it the same "optimum" as referred to in the paper "Theater Acoustic Recommendations of the Academy Research Council Theater Standardization Committee" (published in the March, 1941, Journal)?

MR. LOYE: Very nearly so. It is slightly under the present optimum, because these measurements were made over a period of years. The optimum reverberation time has increased slightly. The desired reverberation in a well designed theater or review room of today is greater than in a room not designed in accordance with modern acoustic practices.

MR. HILLIARD: Under ideal conditions optimum reverberation can go up approximately 10 per cent if all the factors are taken care of. Undoubtedly in the future we shall see the studios tending to meet this optimum as new review rooms and scoring stages are built that will thoroughly diffuse the sound.

MR. FRIEDL: You started by talking about an ideal review room and I believe described some dimensions as being  $54 \times 32 \times 20$ , or approximately 35,000 cubic-feet. Then you went on to find the revenue produced by the ideal theater or the average theater. I believe you ended with 1000 seats and 150 cubic-feet per seat, which is slightly different from the Research Council's 125 cubic-feet.

MR. LOYE: The number of cubic-feet per person varies with the size of the theater; so the Research Council was right and I was right.

MR. FRIEDL: What would 150,000 cubic-feet be in three dimensions?

MR. LOYE: About 100 feet long by 60 feet wide by 25 feet high.

MR. FRIEDL: As low as 25 would be acceptable?

MR. LOYE: Yes.

MR. HILLIARD: A distinction should be made here. Mr. Loye's survey shows what actually exists in the field. The information in the Research Council paper refers to what would happen if we had complete control of the situation and could make it ideal.

MR. KELLOGG: What influence does too dead a review room have on the judgment of the man who is reviewing? Suppose that the reviewer is trying to make up his mind whether some change should be made in the music when it is recorded as, for example, a reduction in the low frequencies. Is there danger that he will try to compensate for the unnatural conditions of the review room by calling for some change in the recording characteristic which is not in fact justified? Is a different kind of music required when listening in too dead a place?

MR. LOYE: I presume that you have in mind what I referred to in the way of a review room quality control by means of keys to increase the low and high-frequency response above what would be normally considered desirable in a theater. The reason for using such keys would be to accentuate the high or low frequencies in order to make it possible to recognize readily extraneous noises or recording faults.



For instance, accentuating the high-frequency response would enable the listener more easily to detect the presence of distortion resulting in false harmonics which make the sound harsh. "Shutter bump" is a recording defect, the presence of which can be detected by accentuating the low frequencies.

It was not to change or to improve naturalness but rather to accentuate faults in the film that I suggested that the keys be provided to extend the review room response characteristic.

MR. HILLIARD: In general, we should like the conditions in the review room to be as nearly like those of the theater auditorium as possible. For that reason we should like the reverberation time, especially in the mid-frequency range, to be as near as possible to what is regarded optimal from both theoretical conditions and the surveys we have made in the field.

MR. FRIEDL: Suppose we have a dead review room where some listening is being done for re-recording to compensate for that deadness, and controls are used to bring the sound up to an acceptable brilliance. The printing is done and the film goes out to the theater, which is less dead than the review room. Your figures show 28 per cent deadness for average review rooms and 8 per cent for average theaters. What is the effect of listening in the theater?

MR. KELLOGG: If the characteristics of the review room and theater (when plotted as reverberation time against frequency) have the same shape—in other words, if neither room tends to accentuate certain frequency ranges more than the other room, then I do not see why there should be any particular effect that would give the mixer a wrong bias, except of course that the smaller room would tend to give better "presence" and freedom from blurring. But this last effect would, I should think, be almost impossible to avoid, and no doubt frequently gives too optimistic an impression of intelligibility.

MR. FRIEDL: Inasmuch as you have referred to deadness in that range, or average deadness in that range, do you relate that to the average of the optimum range or the lower limit of that range? You have suggested a range of 200 to 2000 cycles: What is the significance of that range? We know the 1000-cycle reference.

MR. LOVE: It is related to the average of the mid-band optimum, not to the lower limit. That range was chosen because a great many acoustical materials are measured at those frequencies and the absorptions are referred to that range.

I have shown you the entire curve in each case, from about 50 to 8000 cycles, and then chosen the average reverberation time over the mid-frequency range covering four frequencies as a convenient single figure to refer to.

MR. FRIEDL: Is it not rather unfortunate to concentrate on a mid-range and form such a mental picture? I will remember 28 per cent for review rooms, but I can not picture your curves. I will also remember 8 per cent for theaters.

The object of high-quality reproduction is to extend the high and low-frequency ends. By poor treatment of the ends we may do more harm than good in the optimal treatment of the 200 to 2000-cycle range.

MR. LOVE: It would be objectionable to refer to the figure representing that limited frequency range, where a more accurate idea of the characteristic is desired.

Inasmuch as I have shown the complete characteristics, I thought it was in order to refer as I did to the mid-range average characteristics. By warning you

that that was what I was doing, I thought that it would not be confusing to do so.

MR. KELLOGG: How much reinforcement of the sound intensity comes from the room reverberation at the live end, where the orchestra sits, and how much at the back end?

MR. LOYE: There was resonance reinforcement particularly in one slide where the characteristic was quite high at the low-frequency end.

MR. KELLOGG: I thought there was a plotted curve for the reverberation time of the room as a whole without discriminating between the two ends.

MR. LOYE: Yes. In every case they were for the room as a whole. They were the average of measurements made with the microphone in several positions in the room.

MR. KELLOGG: How much of the absorption was concentrated near one end?

MR. LOYE: In all the measurements that we have made the reverberation is surprisingly uniform, or nearly equal to the average, regardless of the position in the room at which the measurements were made.

For instance, if you were on a scoring stage and made a measurement in the orchestra shell, you would find very little, if any, difference between that reverberation time and one made with the microphone in the dead end of the stage. One reason is that even though the acoustically hard materials may be placed largely in the shell end of the stage, the sound energy built up in the stage due to reflections from the surfaces would be delivered into the dead end of the stage after the sound had been cut off, thereby sustaining the sound in this end as well as the live end.

Therefore, in making the measurements, unless a two-slope effect can be detected, due to the feeding of the energy built up in the shell into the dead end of the stage, it is difficult to measure very much difference in reverberation times between the ends.

MR. KELLOGG: I should expect that a measurement of total reverberation time would be very slightly affected by which end of the room you made it in. On the other hand, while the sound is being produced, there is a noticeable difference in reinforcement. For example, when walking from one end of the room to the other one senses a considerable difference in how loud one's own voice sounds. Similarly, the orchestra gets the benefit of a much livelier room than they would if they sat in the other end. Is there any way in which such an effect can be evaluated? It would probably not be by ordinary reverberation time tests, but perhaps by energy level measurements while a warble tone is being radiated.

MR. CRABTREE: In the early days of sound recording some of the stars refused to talk because presumably their voices did not have sufficient low-frequency response. I notice that at least one of them has now begun to talk, and I have been wondering whether frequencies have purposely been introduced into the recording. If so, how is it done; by the use of trick recording rooms with excessive low-frequency response, or by the use of filters; or is it done in the re-recording?

MR. LOYE: The frequency range has been extended to the low part of the spectrum by improved recording and reproducing equipment. One of the principal troubles in working with review rooms, particularly small ones, is to avoid room resonances. Many improvements in acoustical design, however, have been made to get rid of the unnatural reinforcement of low-frequency response due to room resonances.

MR. FRIEDL: There was a discussion of sound-sources in the Research Council paper mentioned before. Can you describe the sound-sources you used here? The other paper showed different characteristics at various positions of the room. I believe you stated that that was not so with your method.

MR. LOYE: The measurements described in the paper presented by Mr. Durst are overall acoustic response measurements of a reproducing system and room. The measurements referred to in this paper are of reverberation time decays. In these latter measurements a warble tone oscillator was reproduced in the room until the sound level was built up to a steady-state condition. The sound-source was then cut off and the reverberant sound decay charted by means of a high-speed automatic sound-level recorder.

MR. SHEA: The general run of review rooms, as Mr. Loye indicated, showed a tendency of the high frequencies to drop below the optimal. I was particularly interested in that because of some recent experiences in connection with frequency modulation in broadcasting studios, in studio acoustics. Initial experience is showing a tendency toward desiring more liveness than has been customary.

MR. LOYE: That is a very natural trend for the reverberation to take. By way of illustration, according to Dr. Knudsen's work regarding sound absorption in the air, if a room, regardless of the size, had perfectly reflecting walls, but the humidity of the room were about 18 per cent, it would be impossible to get a reverberation time greater than 0.62 second at 10,000 cycles. This is due entirely to atmospheric absorption at that humidity.

MR. SHEA: I was not speaking so much of the difficulties of getting it, but the effect of listening to reproduction under those circumstances is a distinctive one of the high frequencies appearing to be livelier than you expect.

MR. LOYE: I have not experimented along that line.



## MEASUREMENT OF PHOTOGRAPHIC PRINTING DENSITY\*

JOHN G. FRAYNE\*\*

*Summary.*—When the spectral sensitivity of positive film is simulated by the use of a suitable combination of phototube and optical filter in the integrating sphere densitometer, the printing density of any type of negative, irrespective of grain size, with any type of base or backing, may be accurately determined. Printing density is practically independent of the type of light-source or filtering employed in the printer. Relationships between printing and visual diffuse densities for various types of negatives have been established.

It has long been recognized that the printing density or density of a photographic negative as seen by the positive emulsion in the printer, may be quite different from the visual diffuse density of the same negative. When the silver deposit and the film base are neutral in spectral transmission, the difference between the visual and print densities is ordinarily not large. Whatever difference exists has been shown by Koerner and Tuttle<sup>1</sup> to be due mainly to the failure to achieve in the densitometer the complete diffusivity of the contact printing process. MacKenzie,<sup>2</sup> however, has shown that when the negative is not a neutral gray, a considerable difference may exist between the printing and visual densities by reason of the difference in spectral response of the film and the eye. The ratio of printing to the visual density is usually called the color coefficient<sup>3</sup> of the negative, and the value of this coefficient depends on the type of the emulsion as well as on the nature of the developing solution. With the current practice of visual density measurement, this factor must be determined for every type of negative employed to insure accurate control of the printing process.

*Spectral Selectivity of Photographic Silver Deposits.*—The recent introduction of fine-grain films for sound negatives has placed great emphasis on the necessity of measuring the printing rather than the visual density of these negatives, for they have a distinctly brownish

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\* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received Oct. 31, 1940.

\*\* Electrical Research Products, Inc., Hollywood, Calif.



appearance which makes the printing density differ widely from the ordinary visual value. This will be readily observed by referring to Fig. 1, which shows the spectral transmittance characteristics of several silver deposits from various emulsions used in sound-recording practice. Curve 1, which shows the least variation in transmittance over the visible spectrum, was obtained from a spectrophotometric analysis of Dupont 213 silver deposit developed as a positive. The visual density of this deposit is approximately the same as that of the three other sound negatives shown in the figure. Eastman Kodak

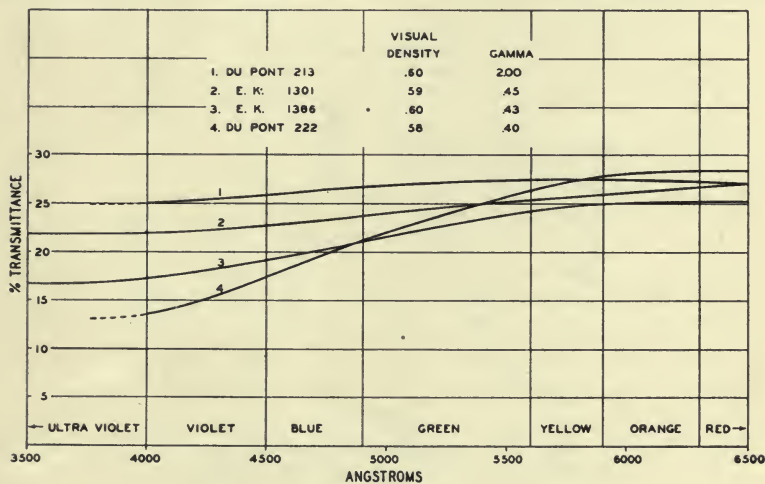


FIG. 1. Spectral selectivity of silver deposits of various emulsions. (Data courtesy of Eastman Kodak & Dupont Film Manufacturing Companies.)

1301 was developed as a sound negative and appears to have, as shown in curve 2, a moderate variation in transmittance from 4000 Å, corresponding to the peak sensitivity of positive film, to 5600 Å corresponding to the peak sensitivity of the eye. Curves 3 and 4 are, respectively, obtained from analysis of Eastman Kodak 1366 and Dupont 222 fine-grain sound negatives, with the latter showing the greatest variation in transmittance between the printing and visual regions of the spectrum. In the latter case a ratio of 2:1 exists between the transmittance at 5600 to that at 4000. This gives a ratio of printing to visual density of 1.28 for this particular silver density deposit. Since emulsions represented in curves 2, 3, and 4 are in descending order of magnitude of grain size, it would appear that the

decrease in transmittance in the region of print spectral response is definitely associated with the grain structure of the emulsion and can not be attributed to any staining of these emulsions in the developing solution.

*Color Sensitivity.*—In a recent paper by Frayne and Crane<sup>4</sup> it was shown that by the use of an integrating sphere densitometer, completely diffuse density measurements of photographic negatives may be obtained, but it was pointed out that in order to obtain true printing density, the visual filter employed in the densitometer would have to be replaced by one that would make the photocell response

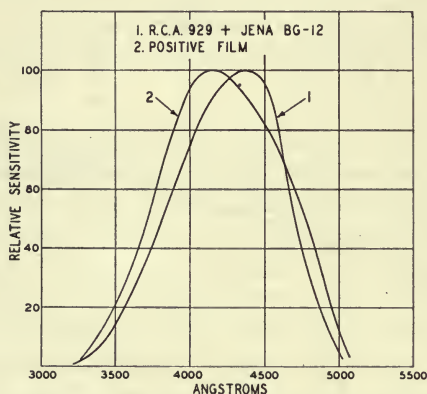


FIG. 2. Comparison of spectral sensitivity of positive film and sphere densitometer for measurement of printing density; corrected for tungsten at 3100°K.

simulate that of the positive film. A similar suggestion had previously been made by Lindsay and Wolfe<sup>5</sup> but they were unable at that time to obtain either cell or filter that would give satisfactory response in the region of print spectral sensitivity.

Since positive film is insensitive in the infrared region, it is necessary to utilize a cell-and-filter combination that is insensitive to this region of the spectrum and is at the same time quite sensitive in the region of the print spectral response. A search of cells suitable for this purpose showed that the RCA 929 Sb-Cs coated phototube was the only one commercially available at the present time. When this cell is used in combination with a Jena BG-12 filter, the response is quite close to that of positive film as shown in Fig. 2. Since it is de-

sirable to use the same cell for "visual" measurements, the 929 cell may be combined with a Jena OG-1 to give a response closely simulating the spectral sensitivity of the eye as shown in Fig. 2(a). Visual density measurements made in this manner were found to be identical with those made with the visual type of filtering previously employed with the FJ-401 cell,<sup>4</sup> and visual measurements referred to in this paper were measured with the spectral sensitivity of Fig. 2(a).

*Printing Density of Sound Negatives.*—In order to demonstrate that the densitometer equipped with the 929 cell and BG-12 filter does read printing density, it was decided to print-through several

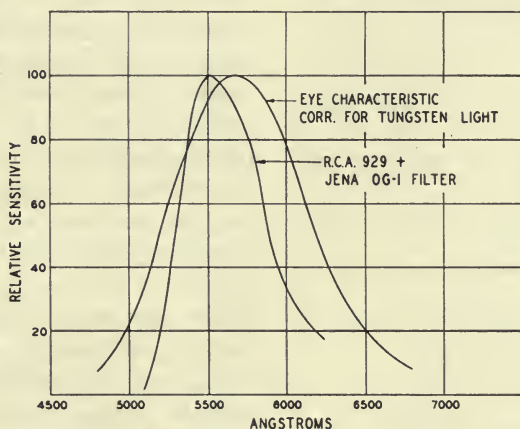


FIG. 2(a). Comparison of eye characteristic and spectral sensitivity of densitometer for measurement of visual densities; corrected for tungsten at 3100°K.

negatives, the printing densities of which were known to vary widely in their relation to the corresponding visual values. Based on the information shown in Fig. 1, Dupont 222 was selected as a fine-grain negative offering the greatest variation between printing and visual densities, while E.K. 1301 was selected as representing a medium-grained sound negative. In addition E.K. 1357 and Dupont 215 were selected as representing standard sound negative emulsions known to have relatively low color coefficients when developed in the ordinary sound negative bath. The four strips were spliced together to form a loop and printed on a standard Bell & Howell printer equipped with an ordinary tungsten light-source. The positive film was developed in the standard manner and the visual diffuse densities



of the printed-through strips were measured on the E.R.P.I. sphere densitometer.<sup>4</sup> The densities of the various negative strips were also measured on the same instrument; first with the visual sensitivity characteristic,<sup>4</sup> and, second, with the spectral sensitivity characteristic of Fig. 1.

The visual diffuse print densities were plotted against the corresponding visual diffuse negative values as shown in Fig. 3. Three distinct apparent printer<sup>2</sup> H&D curves result. Curve 3 represents

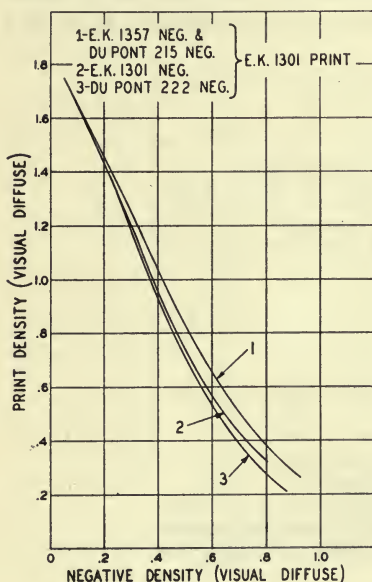


FIG. 3. Apparent printer H&D curves for various sound negative emulsions.

both 1357 and 215, which appear to have almost identical printing characteristics. In Fig. 4 the same print densities are plotted against the negative density values obtained with the characteristic of Fig. 2. To avoid complexity in plotting, points for 1357 are omitted. A smooth curve may be drawn between the three remaining sets of points. Examination of the curves in Fig. 3 shows that any visual negative density, for example, 0.6, on 222, 1301, and 215 will give three distinct values of print density: namely, 0.53, 0.57, and 0.65. On the other hand, it will be noted in Fig. 4 that irrespective of the type of negative employed, a given negative density of 0.6 as measured in this case for any of

the negatives will give only one print density value. In other words, the density values as measured in Fig. 4 correspond to the densities of the three types of negative as seen by the positive emulsion in the actual printing process. It is apparent, therefore, that the integrating sphere densitometer with proper filtering permits a true measurement of the printing density of the various types of emulsions which are commonly employed as sound-recording negatives.

*Printer-Light Spectrum and Printing Density.*—Since the prints thus far analyzed were made on a printer equipped with an unfiltered tungsten light-source, it was thought desirable to repeat the tests on



printers equipped with ultraviolet filters and other light-sources such as mercury arcs, in order to determine whether the printing densities of the various negatives are dependent to any marked degree on the spectral composition of the printing light. Accordingly, two of the test negatives previously employed, namely, the fine-grain 222 and the standard 215 sound negative emulsions, were again printed under four different conditions: (a) with unfiltered tungsten light, (b) with tungsten light filtered through a Corning 584 ultraviolet filter, (c) unfiltered mercury light, (d) mercury light filtered through the Corning 584. Due to the variation of light efficiency of the various light-source and filter combinations, no attempt was made to secure in the various tests the same print density from any given negative density. This condition has no bearing on the conclusions drawn from the tests.

The results of printing with unfiltered tungsten light and with the same light filtered through a Corning 584 are shown in Fig. 5. Curve 1 is similar to the curve of Fig. 4, while curve 2, for the ultraviolet printing condition, shows a slight separation between the 222 and 215 curves at the higher negative densities. Curve 1 of Fig. 6

gives the results for printing with an unfiltered mercury arc. One curve may be drawn through the two sets of points. Curve 2 represents ultraviolet printing with the mercury arc. A slight separation of 215 and 222 is again apparent for the higher negative densities. However, for all the printing conditions, negative densities in the range of 0.5 to 0.7 ordinarily employed in variable-density negatives, simulate closely the actual printing densities whether tungsten or mercury arc sources, filtered or unfiltered, are employed in the printer. This is undoubtedly due to the relatively small shift in peak sensitivity of positive film at 4100 Å for unfiltered tungsten light to a

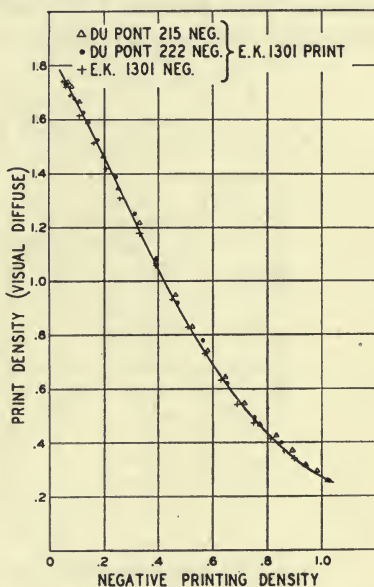


FIG. 4. True printer H&D curve for various types of sound negative emulsions.

peak of about  $3800 \text{ \AA}$  for the filtered condition. Over this region there is little change in the spectral absorption of the negative deposit, as may be noted by referring to curves of Fig. 1 in the region below  $4000 \text{ \AA}$ . Since unfiltered tungsten and mercury arc light are predominantly used in present-day printers, the use of the *BG-12* filter, which permits accurate measurement of printing densities for these conditions, appears logical even though it does introduce a slight error for ultraviolet-equipped printers. Whenever ultraviolet printing predominates some other filter more nearly matching the ultraviolet source could readily be substituted for the *BG-12*.

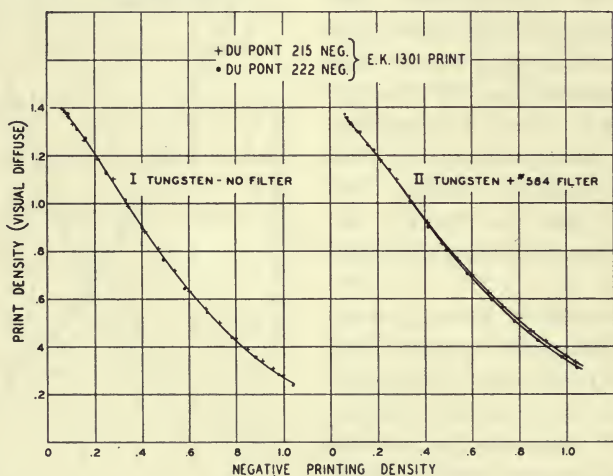


FIG. 5. Illustrating effect on printer H&D curve of combining ultraviolet filter with tungsten printer light-source.

*Printing Density of Picture Negatives.*—The discussion thus far has been limited to printing density with various types of positive emulsions such as are used for variable-density negatives. Since panchromatic negatives are supplied in a variety of grain sizes with non-halation backings of various spectral hues, it was decided to repeat some of the tests previously described on a series of panchromatic negatives in common use in the motion picture industry. Accordingly, three negative strips were selected from Dupont *Superior*, E.K. *plus X*, and E.K. *1203* emulsions. The first two emulsions appear to differ mainly, as far as printing is concerned, in the color of the anti-halation backing employed, while the E.K. *1203* is a fine-grained duplicating motion picture negative. These strips were

printed through on positive film and the densities of the negatives and prints measured as indicated previously. The curves in Fig. 7 show visual print densities plotted against corresponding visual negative densities. Three distinct apparent printer H&D curves are found. It will be noted that the curves for Dupont *Superior* and E.K. *plus X* remain parallel, being separated by a fixed distance of 0.03. This represents the difference between the visual densities of the respective non-halation backings. It will also be noted that the curve for E.K. *1203* departs more and more from the other curves as the high nega-

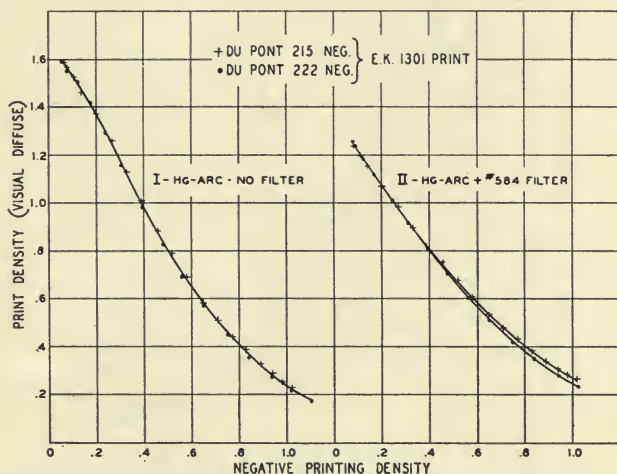


FIG. 6. Illustrating effect on printer H&D curve of combining ultraviolet filter with mercury arc printer light-source.

tive densities are reached, in a manner quite similar to that in which the fine-grain 222 curve departs from the 215-1357 curve of Fig. 3. The curves in Fig. 8 show the results of plotting the print densities against the corresponding densities of the panchromatic negatives as measured by the sphere densitometer with the spectral sensitive characteristic of Fig. 2. Here a single smooth curve may be drawn through all three sets of points, indicating that the density values of these three different panchromatic negative sensitometer strips as thus determined are identical with the true printing densities of the negative.

*Relationship of Printing to Visual Density.*—The curves in Fig. 9 show the relationship existing between printing density and visual

diffuse density for several of the negatives that have been described in this paper. It will be noted that in no case does a true linear relationship exist between printing and visual density. The ratio of printing to visual density is more nearly a constant for the standard emulsions, while the departure from linearity increases as the grain size is reduced. This indicates that the color coefficient<sup>2</sup> of these various negatives is not a constant but is a function of the negative

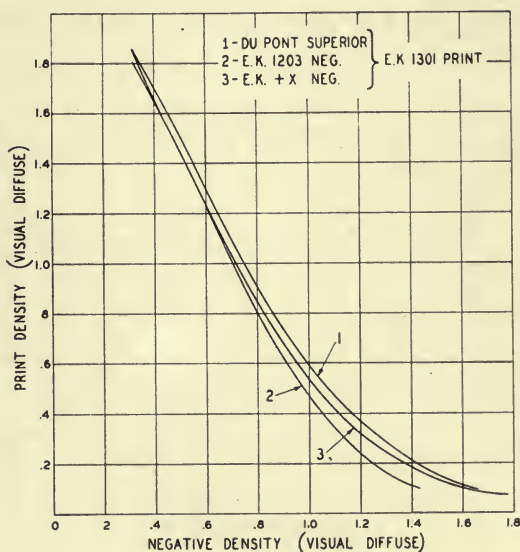


FIG. 7. Apparent printer H&D curves for various panchromatic picture negatives.

density. The equations for the four curves of Fig. 9 are approximately as follows:

Emulsion	Equation
222	$Dp = 1.12Dv + 0.0033e^{4.05Dv}$
1301	$Dp = 1.07Dv + 0.0015e^{4.45Dv}$
215	$Dp = 1.05Dv + 0.0004e^{5.00Dv}$
1203	$Dp = 0.065 + 1.07Dv + 0.0002e^{4.6Dv}$

Where  $Dp$  = printing density and  $Dv$  = visual density.

Since the printing density is definitely related to the spectral selectivity of the silver deposit, the presence of the exponential term



in the above equations would indicate that the spectral selectivity is a function of the amount of the silver deposit and that the color of the image is to be attributed in part at least to light-scattering by the grain groupings rather than to a developer stain. The linear part of the equations may be attributed to the existence of some color, the spectral composition of which is not affected by the amount of the silver deposit.

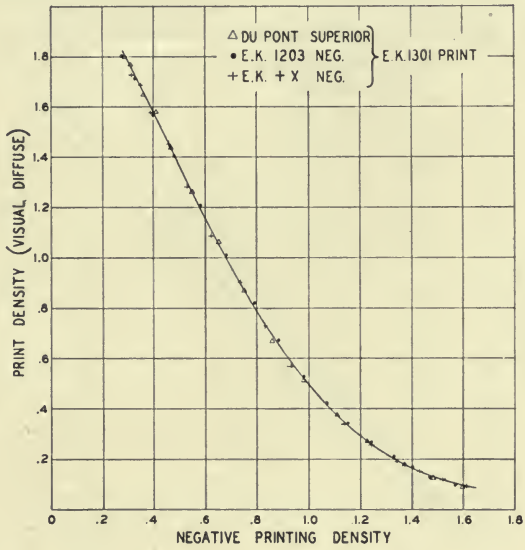


FIG. 8. True printer H&D curve for various panchromatic picture negatives.

*Printing Density in Practice.*—Since a method has been found for measurement of negative printing density, it would seem highly desirable in laboratory practice to substitute this technic for the present practice of making visual measurements of photographic negatives. While the latter may be used satisfactorily for control of the developing solutions, the values of density and gamma obtained from visual measurements are not all representative of the actual density or gamma of the negative that is effective in the printing process. This is well illustrated in Fig. 10, where visual and printing H&D curves are plotted from the same sensitometer strip on the fine-grain 222 emulsion. In this case the visual gamma of 0.49 actually becomes 0.61 in the printing process. The latter value must therefore

be considered the true gamma of the negative since it is the value which is the determining factor in the overall contrast of any print made from this negative. Similarly if the sound-track density on this particular film is considered to be 0.65 on a visual basis, the true density as seen by the positive emulsion is actually 0.78. It will also be observed that the shoulder is less abrupt on the printing density H&D curve which makes the characteristic more favorable for variable-density recording than would appear from an inspection

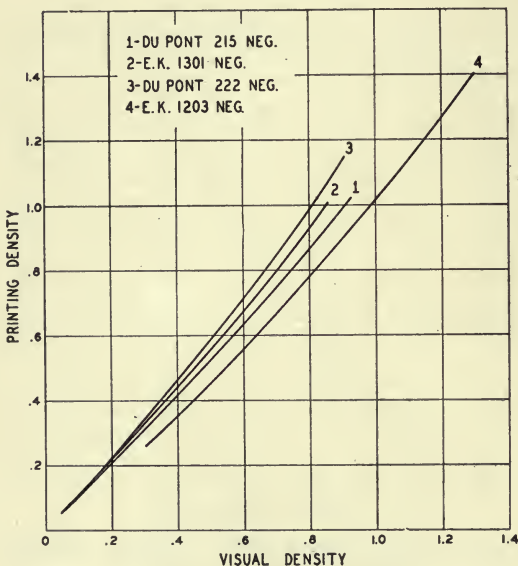


FIG. 9. Relation of printing to visual density for various photographic negatives.

of the visual H&D curve. These observations lead to the obvious conclusion that the substitution of printing for visual densities makes possible a more accurate interpretation of the true photographic qualities of the negative.

From the practical laboratory standpoint, the substitution of printing for visual density control eliminates some of the most confusing elements in the processing operation. At the present time it is necessary to establish printer factors for each type of negative in order to permit accurate setting of the printer exposure for the particular negative being printed. Since we have seen that the color coefficient

is not a constant but a function of density value, no single printer factor will cover the operating negative density range. The chances for error in this procedure are too well known to require further comment here. With the substitution of printing density control only one calibration for each type of printer is necessary, no matter how many different types of negatives are employed.

*Conclusions.*—It has been shown that when the integrating sphere type of densitometer is equipped with a combined cell and filter that gives an overall spectral response similar to that of positive film, photographic printing densities may be measured of either sound or

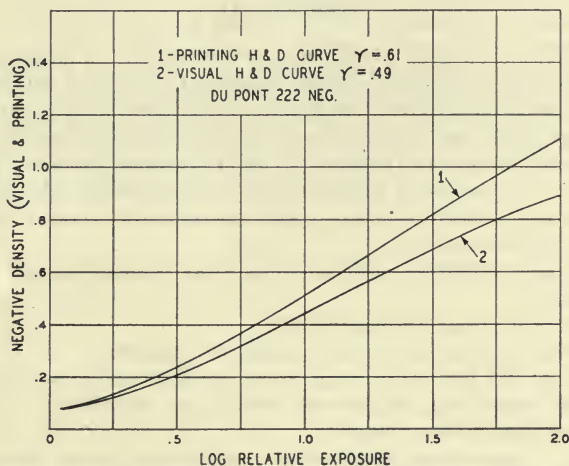


FIG. 10. Illustrating printing and visual H&D curves for Dupont 222 sound negative.

picture negatives varying widely in grain size and color of base. It has also been shown that the printing density is relatively independent of the type of light-source or light-filter employed in the printer.

The addition of this alternative type of filtering to the integrating sphere densitometer makes it possible to eliminate all color coefficients and other devices currently employed in the "timing" of various types of negatives. The use of such an instrument, therefore, should clear up the confusion which exists at present in laboratories employing diverse types of negatives and should increase considerably the efficiency of the film processing operations.

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## DISCUSSION

MR. LINDSAY: You have ably confirmed the necessity of adopting the positive emulsion spectral response characteristic for an accurate determination of the printing density of negative materials. Do you find that positive films as well as the fine-grain films all have the same spectral response characteristic?

DR. FRAYNE: I have been informed by the Dupont and Eastman people that that is the case. If, however, a fine-grain positive film is introduced with a different spectral sensitivity from the existing types, that will involve only a slight change in the filter in the densitometer.

MR. CRABTREE: Will the densitometer take care of images having a relatively high color index?

DR. FRAYNE: It should take care of any.

MR. CRABTREE: That is, provided you find the right filter?

DR. FRAYNE: We use the Jena glass filters made by Zeiss, from which we can get almost any range from the infrared down to the ultraviolet. The domestic supply of these filters is rather limited.

DR. DAILY: Light-valve gamma studies on different types of fine-grain variable-density negative stocks have indicated a number of variations including (a) 11b gamma curves with a slope as much as 30 per cent greater, or 10-15 per cent less than the light-valve gamma; (b) toe curvature occurring at different densities on the light-valve and 11b curves; (c) light-valve curves in some cases indicating an increase in gamma for densities where the 11b curves are still straight or indicating a shoulder. The measurements of density in each case were made with an electrical densitometer which has essentially visual characteristics. Does the new densitometer confirm these types of observation, both on the negative and through the printing operation?

DR. FRAYNE: All I can say is that the densitometer as described measures the total flux transmitted through the deposit, as was pointed out in the previous paper. The filtering described here simulates the spectral response of the positive film. All I am trying to prove is that the instrument measures the actual printing density, both from the standpoint of diffusion and color. If the phenomenon you referred to is involved in either of those conditions then the densitometer will take care of it.



MR. LINDSAY: If you think that the positive spectral response is desirable in the measurement of negative materials, do you agree that the optical and spectral characteristics of an average sound-projection machine should be simulated for the correct measurement of positive materials and fine-grain prints? If we look at the negative and fine-grain films as the positive or print sees them, then we should look at the prints as the projectors see them, optically and spectrally.

Dr. FRAYNE: When we come to measuring print densities, that is something else. On a print we have a sound-track and also a picture. As far as the sound-track is concerned, it is obviously logical in view of the stand taken here that the sound-track densities should be measured as the photocell sees them in the reproducing equipment, with the same spectral response and the same light scattering, and so on.

There has been some work done along that line. We have in our laboratory what we call a projection type densitometer. There is, however, no instrument available to the public at this time. Nothing has been standardized. It would mean more or less standardizing the optics of the reproducing machines.

At the present time there is a wide variation in the optics of reproducing machines. I do not believe it would be practicable at this time to put on the market a densitometer that would measure print densities in the manner proposed.

I might also point out that the picture is seen visually, of course, but not diffusely. That calls for another kind of densitometer. Whether the resulting confusion would be worth the effort, I do not know.

## AN IMPROVED HORN PLAYBACK EQUIPMENT\*

C. R. DAILY\*\*

*Summary.*—A mobile two-way horn system has been constructed to provide improved quality playbacks to sound-recording stages, the same horn equipment also being useful in connection with high-level announcing systems. The material in this paper covers certain of the mechanical and electrical design features of this horn system, together with brief descriptions of other new portions of the playback system, including an equalized feedback type disk playback amplifier, a playback control system for the production mixer, and a compact and easily handled high-quality speaker for use in connection with the direct recording of low-level playbacks.

Playback equipments serve an important purpose on production stages and the need of high quality in such equipments should be emphasized. All portions of the playback system should be carefully designed to improve the quality and to facilitate their operation on the stages. The need of high-quality disk playbacks is illustrated in the case of direct film recording from low-level playbacks. For this type of work, the director needs to be able quickly and accurately to judge the quality of the recorded take so that he can make a proper selection of the desired take for subsequent use on the same day, using the disk for further high-level playback work. If any portion of the playback equipment produces poor quality, the director is unable to make the proper selection of takes, forcing him to wait until the following day to hear the film takes. This type of delay is costly to production. In the paragraphs to follow, a mobile two-way horn system will be described which serves the dual purpose of providing high quality and sufficient flexibility for use in any production service. Since a new playback control system was needed to go with this horn, a brief description will be given also of some of its component parts, including an equalized-feedback disk reproducing amplifier, playback control box, and a small high-quality horn.

A schematic drawing of a normal recording and playback system is shown in Fig. 1. The sources of playback material may include (a)

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\* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received October 15, 1940.

\*\* Paramount Pictures, Inc., Hollywood, Calif.

film reproduced from fixed or portable units, (b) lateral-cut acetate recordings reproduced from fixed or portable units, and (c) vertical cut recordings.

The outputs from each of these sources are amplified to a uniform speech volume before transmission to the playback control unit which is mounted on the stage mixer's console. The mixer is then able properly to control the volume to the horn units, head-phone extensions, and microphone input position. The two-way horn system, used for high or low-level playback, is mounted on a dolly to permit ready movement about the stage or on location, while a Western Electric 750-A speaker, mounted in a small cabinet, may be connected to the

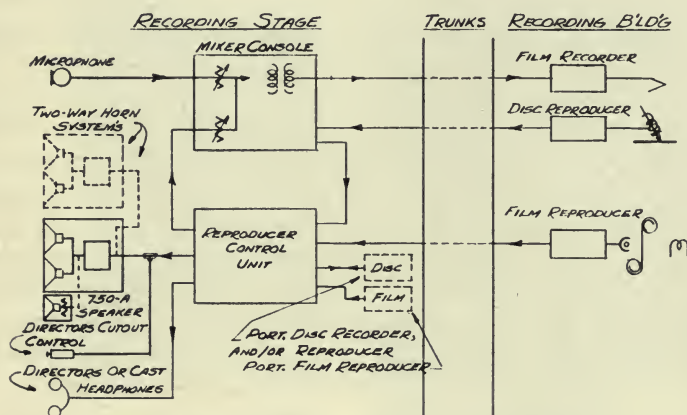


FIG. 1. Block diagram of stage playback system.

output of the horn console amplifier system when high-quality low-level playbacks are needed.

*Two-Way Mobile Speaker System.*—A front view of the two-way speaker console is shown in Fig. 2. The unit is constructed in two sections: (a) the horn unit, including the two-way speaker system, field supply power unit, dividing network, low-pass filter, extension cable connections, and storage space for accessories, and (b) a four-wheel steerable dolly supporting the horn unit mounting plate, 40-watt power amplifier, patching panel and cable reel. The horn unit may readily be separated from the dolly, as shown in Fig. 3, when it is necessary for the horn unit to be used on high parallels or suspended from the ceiling. When mounted as one unit, the two sections are secured together by trunk hasps and a positioning detail. The horn



unit can be rotated to any desired position, this facility frequently being useful on the stage when it is desired to direct the horn output in a particular direction.

The horn dolly is equipped with four 14-inch wheels with pneumatic tires. The steering handle mounts a hand-operated brake lever for use in holding back the dolly when moving it over sloping ground on location or to assist in holding it when moving it down steep ramps.

The horn dolly has a wheel base of 32 inches with an overall length

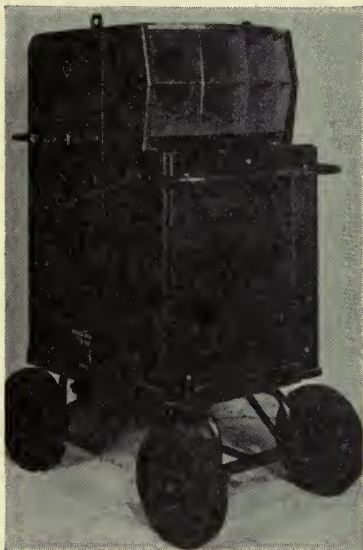


FIG. 2. Two-way speaker console; front view.

of 46 inches required for storage. The unit is 44 inches high and  $28\frac{1}{2}$  inches wide, measuring from the tips of the axles when they are clamped in the closed position. By loosening hand-screws, each axle may be pulled out 6 inches, resulting in a maximum width of the unit of  $40\frac{1}{2}$  inches when it is necessary to increase the stability of the unit when moving it over rough ground or obstructions. The horn console and dolly together weigh approximately 613 pounds, with the separable horn unit weighing approximately 295 pounds.

The cable reel compartment is shown in Fig. 4. Normally 200 feet each of power and speech cable are stored in this compartment. A rear view of the horn console is shown in Fig. 5. The cable reel handle folds in flush in a recess in the back of the console. The brake arm on the steering handle is also indicated in this photograph. Access to the high-frequency horn compartment, which also mounts the horn power units, low-pass filter, dividing network, and connecting plugs, is obtained by a hinged door available from the rear of the unit.

A schematic wiring diagram of the horn console is shown in Fig. 6. The output from the mixer-operated playback control unit is connected to the horn input. A high-impedance volume control can be patched to this input position if necessary, although the volume is normally controlled by the mixer. The input connections of two or



more of these horn units may be patched in parallel to provide greater acoustic power output or to provide better distribution of volume on the set. A push-button type extension cut-out control may also be patched to the input circuit to permit the director to turn the horn unit on or off at any time. A view of this cut-out control is shown in Fig. 7. A standard six-conductor cable plugs into the base of this unit for connection back to the horn unit.

A modified RCA *MI-4288-D* power amplifier provides the necessary gain and carrying capacity to operate the horn system properly for

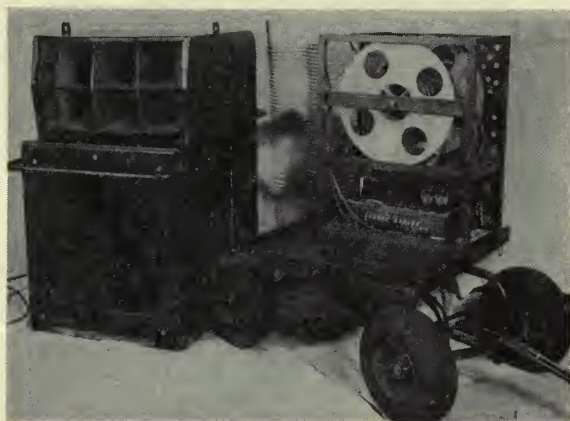


FIG. 3. Two-way speaker system: speaker unit and dolly with associated equipment.

high-volume stage use. The amplifier, normally high impedance at the input, has been equipped with a shielded bridging-type input transformer to provide a gain of 33 db when terminated with 500 ohms on its input. The frequency characteristic is substantially flat and the noise level sufficiently low for normal operations.

A low-pass filter connected in the amplifier output circuit has been adjusted to give a high-frequency acoustic response characteristic approximating that of a modern theater system. A 500-cycle dividing network supplies the modified Lansing "Iconic" speaker system which consists of a type 815 low-frequency speaker mounted in a special cabinet with an acoustic chamber similar to the standard Iconic horn. A type 285 high-frequency horn unit is mounted on a

type 805, eight-cell high-frequency horn, this entire unit being mounted on top of the low-frequency speaker cabinet and enclosed in the main console housing. The higher-carrying-capacity theater-type high-frequency horn and driver unit were used on account of the high volumes occasionally demanded of this equipment.

*Light-Weight, Low-Level Speaker System.*—Frequent use is found for a high-quality, light-weight speaker system, for the following uses: (a) low-level playbacks requiring the horn to be inconspicuously located very close to the singer, and of such quality that the



FIG. 4. Horn console cable compartment.

acoustic leak from the speaker to the microphone will match in quality with the same music subsequently re-recorded from film, (b) horn hung on the camera dolly and carried along to follow the action, (c) a horn carried along the side line of the action. For these services, which can not readily be handled by the larger two-way horn system, a Western Electric 750-A speaker has been mounted in a small Celotex-lined box, as shown in Fig. 8. This horn unit may be connected to the output of the console amplifier in place of the normal two-way system, and is protected from overload by a 12-db pad. The excellent quality of this speaker has been very useful for low-level playback service as a supplement to the two-way system for the same service.

*Lateral-Cut Acetate Reproducing System.*—Western Electric 9A reproducers are currently used for the reproduction of acetate records cut with Western Electric *D-85264* disk recorder arms. For this service the reproducers are mounted on a specially cast bracket which is attached to the recorder carriage so that the reproducer can move with the action of the lead screw. For playback work, the carriage is run out until the axis of the reproducer arm is tangent with the desired starting cut on the record. When the record is reproduced, the arm moves laterally at the same pitch speed as the groove, reducing tracking errors to a minimum. The reproducer output is connected through the special reproducing amplifier, to be described in the next paragraph, and thence to the playback control unit and horn system.

*Equalized Playback Amplifier.*—A disk reproducing circuit requires the use of a low-frequency equalizer to compensate for the attenuated low-frequency characteristic of the recorder. The shape of the curve required may be at the rate of 6 db per octave, or less, with the cross-over frequency between essentially constant amplitude and constant velocity occurring at frequencies between 300 and 1000 cycles, depending upon the cutter design and disk material used. It has been a common practice to build the post-equalizer and initial playback amplifier as separate units. In the design of this system, however, it was found expedient to combine the equalizer and amplifier in the same unit, and for this purpose Mr. H. E. Fracker, of this organization, developed the feedback equalized design shown in Fig. 9. This circuit uses a Wien bridge connected in the feedback circuit and has the following advantages: (a) only one coil is required in the low-level circuit between the reproducer output and the first amplifier

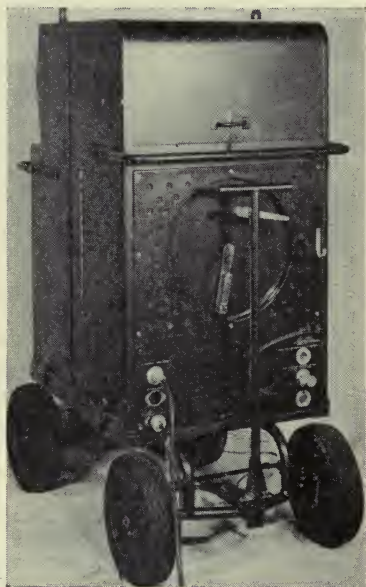


FIG. 5. Two-way speaker console; rear view.



tube, thereby minimizing the danger of a-c pick-up; (b) this type of equalizer may be made broadly resonant at any desired low frequency; (c) the response of such an equalizer falls off at frequencies less than

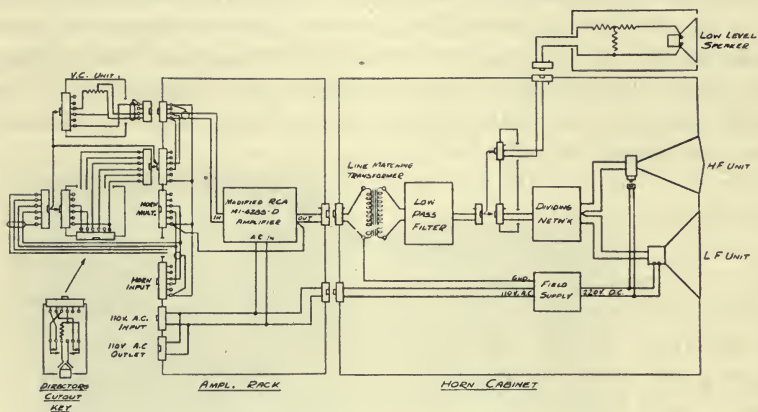


FIG. 6. Schematic diagram of horn console.

that would be transmitted by a flat low-frequency characteristic; the resonance frequency, minimizing the reproduction and disturbance effects of low-frequency machine and record-rumble noises

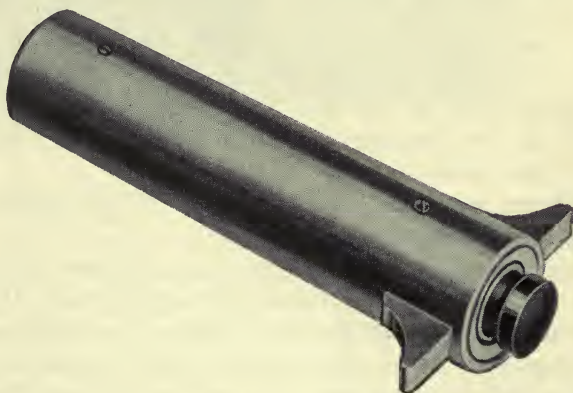


FIG. 7. Director-cut-out control.

(d) the characteristic may be readily adjusted to the desired shape; (e) construction costs are less for this design than for a separate equalizer and amplifier.



In an amplifier of this type the resistance  $R_6$  (Fig. 9) is first set at the value needed for bias on  $V_1$  (RCA 12SF5). The resonance frequency  $f_0$  is next selected at the desired frequency of maximum low-frequency response. With  $R_6$  and  $f_0$  defined, the three remaining arms of the bridge may then be determined, *i. e.*,  $R_3$ ,  $R_2 - C_1$  and  $R_4 - C_4$ . Since a Wien bridge normally has a very sharply peaked characteristic, the shunt arm  $R_5$  is added to broaden the curve by the desired amount.  $C_5$  is used as a blocking condenser so that the addition of  $R_5$  will not affect the bias conditions of the tube.  $R_{11}$  is used to adjust the characteristic and overall gain required. A 9-ohm, 6-db pad,  $P_1$ , and a 9:65,000-ohm input transformer are used on the input of the amplifier. An RCA 12J5-GT tube has been used for  $V_2$ , coupled to a 16000:500-ohm output transformer. The 7 $\frac{1}{2}$ -db,



FIG. 8. Western Electric 750-A speaker.

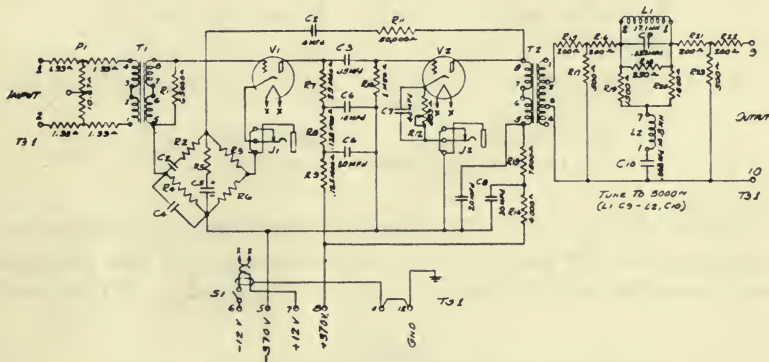


FIG. 9. Schematic diagram of disk playback amplifier.

500-ohm pads,  $P_2$  and  $P_3$ , connected to the output of the amplifier are used to adjust the output of this amplifier to match existing film playback facilities. The characteristic of the amplifier is shown by curve A in Fig. 10. The 5000-cycle suppressor connected in the out-

put circuit of the amplifier is used to obtain the desired overall recorder-reproducer-acetate response characteristic. The characteristic of the amplifier, including the suppressor equalizer, is shown by curve B. The overall disk recording and reproducing characteristic of the acetate system as measured from the cutter amplifier input to the equalized reproducing amplifier output is shown in Fig. 11. The distortion and output characteristics of the amplifier are indicated in Table I. These data indicate an adequate margin of the carrying capacity for the amplifier for this type of service.

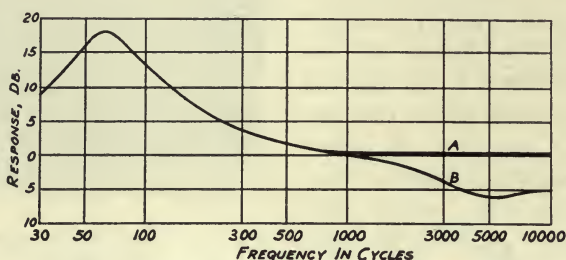


FIG. 10. Response of disk playback amplifier.

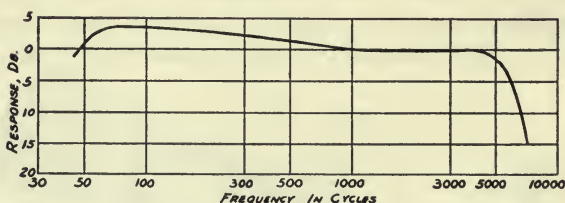


FIG. 11. Overall response of disk recorder, acetate recorder, and reproducing amplifier.

*Playback Control Box.*—The output of the equalized disk playback amplifier is further amplified to match the output of film playback equipments before transmission to the recording stage. All playback

TABLE I

*Distortion and Output Characteristics of Disk Playback Amplifier*

(Measured in a 500-Ohm Termination on Output of  $T_2$ )

1. 400-cycle total harmonic distortion of amplifier	0.35% at + 9 db/6 mw 1.00% at +15 db/6 mw
Normal maximum output from disk records	0 db/6 mw



console ; (5) bridging circuit across the main recording amplifier output for connection to portable stage playback recording equipment.

The loss of this bridging circuit is sufficient so that an accidental short-circuit or open on the transmission line to the portable playback equipment will not affect the quality of the main film recording equipment. The diagram of the playback control box is shown in Fig. 13. The outputs of the two mixer circuits are combined through a hybrid coil  $T_3$  to the line-terminating resistance  $R_5$ .

This type of playback system has proved to be very convenient in use on production stages. The respective equipments are easily patched together, and combined with the quality of the horn system the equipment is capable of producing a very satisfactory disk playback service. The writer wishes to acknowledge the assistance in the design of this equipment of Messrs. H. E. Fracker, C. W. Hyten, and D. E. Ross, of Paramount Pictures, Inc.

#### DISCUSSION

MR. CRABTREE: Under what conditions are playbacks required?

DR. DAILY: Vocal numbers and the accompanying orchestrations are rarely recorded at the same time. A disk or film record is first made of the orchestra, which is subsequently played back at low level to the singer for the synchronized recording of the vocal number.

Playbacks are used also for rehearsals of dance routines and similar types of material. After the cast has developed the necessary perfection of timing and action, the scene is photographed, using the playback to provide the necessary synchronism of original prescored music with the photographed scene. The original music, sound effects from the action, and the photography are then combined in the cutting and dubbing departments.

MR. CRABTREE: In the case of an orchestra, do they demand an immediate playback to determine quality?

DR. DAILY: Generally, yes.

MR. CRABTREE: Has the Miller system been used extensively for playback work?

MR. TASKER: So far as I know the Miller system is not in use in any Hollywood studio, although it does afford immediate playback. All the playbacks, if they are instantaneous, are from disks; otherwise they are from film developed in the interim.

May I add one word to what Dr. Daily said?

In the system he described first, the photography takes place during the second of the steps mentioned. The horn is located close to the actor being photographed. The orchestral music is reproduced at a low level so that actor may sing for the camera and the microphone. This is like the recording of dialogue, in that the voice appears in the final picture, plus a dubbing from the orchestra track.

MR. CRABTREE: Superimposed on the very low level previously recorded?



MR. TASKER: Yes; and obscuring and wiping out that low level that was just audible on the set.

DR. DAILY: Recordings to low playbacks are generally made with directional microphones to reduce to a minimum the amount of playback material picked up. The portion of the playback that is picked up by the microphone should be of high quality in order to match the quality of subsequent re-recordings of the same material.

MR. SKINNER: You apparently can fix the playback right into the track at the time you are making the playback. That increases the quality and obliterates the ordinary sound that comes into the room. Is that correct?

DR. DAILY: The direct electrical connection between the playback circuit and the film recording channel is rarely used in connection with playbacks to the stage. This facility, however, does make possible the direct dubbing from the stage of two playback sources to obtain a single new disk which is then immediately available for further playback service.

MR. TASKER: The direct-tie process to which you referred was of much greater usefulness prior to the availability of a high-quality horn of the sort here described. In the making of a high-playback scene, such as a dance number, we always need a record of the sound for use of the film editor. Recording the track by means of a microphone was very unsatisfactory when the sound originated from the previously employed poor-quality horn. Consequently, it was of great advantage to be able to tie directly across to the cutting channel and get a somewhat improved recording.

It should not be assumed that the procedures mentioned this morning anywhere near bracket the methods employed in the recording of music. In a recent survey we discovered that at Paramount alone there are upward of seventy-eight variations of the manner in which music finally reaches the screen. We have mentioned here only two or three typical cases in which playbacks take a part in the final presentation of the music.

MR. CRABTREE: Suppose you were recording a piano duet, for example. What is the difference in the final result between recording the two pianos simultaneously and recording one pianist, and then running the same film through the recorder and recording the other pianist synchronously. In other words, one is additive result and the other one is a single recording.

MR. TASKER: Technically, so far as the recording of the sound is concerned, there would be a slight loss. There would be more likely a loss in the performance of the people. It would be better for them to play actually as a duet in the first place. One can imagine, however, that it could be done.

Suppose the duet occurred in the midst of a big orchestral number and the one piano for some reason was on the left side of the stage and the other on the right side, with the orchestra massed in the middle. Then it might not be possible to get a good duet recording. It might be better to record the one piano and play it back to the other pianist; then play the second piano and weld the two together.

MR. CRABTREE: You are recording one and then the other on the same film. You are not recording on a separate film.

MR. TASKER: I did miss your point entirely. You are proposing a scheme of double photographic exposure, with which I have had no experience, although I

suspect it would not work very well. It would involve an adjustment of the exposure. The sum of the two exposures must give us the required mean density. It would be a complex procedure which we do not even contemplate because it seems needlessly difficult. For example, it would be quite difficult—not impossible, to be sure—to synchronize those two.

MR. CRABTREE: Assuming they are synchronized.

MR. TASKER: Assuming that, it should be possible. I have no idea whether it has ever been done, and what the result was if it has. It is very easy, however, to make two separate recordings and dub them together. That whole process has been done.

DR. DAILY: The addition of two electrical signals produces increases and decreases of amplitude, depending upon the relative phases of the two signals at a given instant. If an initial exposure has been made on a negative, however, the addition of a second exposure would normally produce only increases in exposure, which would probably produce a distorted signal.

MR. STROCK: There is one correct spot for photographic exposure on the negative. You would have to reduce the illumination which would change the result. You would bring in harmonics. That result would be a bit disappointing, I would suspect.

## GENERAL AND DESIGN CONSIDERATIONS OF LOW NOISE MICROPHONES\*

A. L. WILLIAMS AND H. G. BAERWALD\*\*

*Summary.*—The physical and physiological side of the problem of thermal agitation noise in microphones is reviewed, in connection with a recently proposed noise rating. Following this, different microphone types are discussed and compared with regard to their noise performance, and to possibilities and inherent limitations of noise reduction. Multiple piezoelectric microphones which lend themselves particularly well to the design of quiet units are treated in more detail. The design principles of the associated tube circuits for full realization of the inherent efficiency or noise performance of microphones are discussed. Application is made to the design of minimum-noise combinations of different microphone types; some performance data are given of an experimental unidirectional model composed of piezoelectric elements and a ribbon.

The thermal agitation noise of high-quality microphones is a problem of increasing importance to the engineer as the communications art becomes more and more refined. To cite an example: the dynamic range of high-fidelity wide band frequency-modulation transmitters is at present definitely limited by the hiss of commercially available microphones. The realization of this kind of limitation is by no means of recent date. After all, a microphone in use is but a member in a whole communication system whose limiting factor, as is well known, is the signal-to-noise ratio, and not its sensitivity. In the case of the microphone, however, other limitations peculiar to electroacoustic devices, which had to be overcome in the course of microphone development, were in the foreground; while not of a principal nature, they were nevertheless difficult to cope with, and thus thermal noise appeared as a more or less distant limitation. While for the "old timer," sensitivity was of prime importance, high fidelity and various directivity features could be achieved with the refinement of the art, but only at the expense of sensitivity: extension of the frequency range requires small physical size to reduce sound-field effects and those due to mechanical natural frequencies.

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\*\* The Brush Development Co., Cleveland, Ohio.



Furthermore, some of the possible and useful combinations of principles of operation and control which would produce responses proportional to certain positive or negative powers of frequency require "flattening," which, while it may boost some parts of the range, invariably involves an overall decrease of response level.

Other things being equal, reduction of sensitivity amounts to decrease of signal-to-noise ratio. Thus the noise problem becomes of increasing importance in modern high-fidelity systems and should constitute an important point of microphone rating and development. There are two main complications. First, the "objective" noise limit of a microphone, which is given by the level of ambient sound that produces an electric response just equal to the agitation noise, has a frequency spectrum which shows, for several important microphone types, considerable variations over the useful range. This is not true with respect to most other elements of communication systems, *e. g.*, for conventional amplifiers. Second, a microphone is essentially a hearing aid; thus it is not the objective noise behavior or, for that matter, the spectral efficiency which is of importance, as in the case of systems not involving human perception, like machine telegraphy or black-and-white facsimile. The noise performance of a microphone must rather be understood in relation to the properties of aural perception, *i. e.*, it must be rated subjectively. This involves an averaging over the useful frequency range, with widely varying weights.

The problem of microphone noise has been discussed in more detail in a recent publication,<sup>1</sup> in which a rating of noise performance, the "Absolute Noise Level" has been proposed. The Absolute Noise Level of a microphone, measured in phon, is defined as the loudness level of the noise (hiss) experienced by a listener of non-impaired hearing faculties in a "dead-quiet" locality *II* containing a speaker that is connected by a transmission system consisting of an amplifier and a corrector network to the microphone in question, which is located in another dead room *I*, gain and response of the system being so adjusted that any signal produced at *I* would be faithfully reproduced at *II*. The Absolute Noise Level corresponds, approximately, to the hearing loss<sup>2</sup> encountered by listening *via* microphone-transmission system instead of directly at location *I*; the difference between the two quantities being given by that between the hearing threshold and the thermal "limit level" of the ear considered as a microphone. This difference is only of the order of 5-10 db for per-



sons of acute hearing, in the region of maximum aural sensitivity.<sup>1,3</sup> The Absolute Noise Level can be obtained from the "Absolute Noise Spectrum" of the microphone by a numerical or graphical process based on Fletcher's and Munson's work on masking and loudness.<sup>4,5</sup> The Absolute Noise Spectrum is the plot of the noise spectrum level  $B$ , at the locality  $II$  of our experiment, *vs.* frequency  $f$ :

$$B(f) = -94 - \alpha(f) + 10 \log R(f)_{K\Omega} \text{ db for room temperature} \quad (1)$$

and involves only the two quantities  $\alpha$  (response level of the microphone in db above 1 volt per bar) and  $R$  (resistive part of the impedance of the microphone circuit), both of which can be readily measured. The above-mentioned process converts this noise spectrogram *via* the corresponding masking audiogram into the auditory pattern of the microphone noise which represents the excitation per length of the basilar membrane. The area thus covered is the "absolute" loudness of the microphone noise, and the associated loudness level, its Absolute Noise Level. As an illustration, Fig. 1 (reproduced from<sup>1</sup>) gives the juxtaposition of the absolute noise spectra and associated auditory patterns for three different microphone types. These are idealized regarding both the flatness of response and the absolute value of the noise spectrum level, the latter being so adjusted that the resulting Absolute Noise Level is 30 phon in all three cases. The first type, which has substantially constant resistance over the frequency range and represents an idealized electrodynamic microphone, produces a maximum of sensation at about 4000 cps or at a distance of about 70 per cent from the helicotrema, respectively, roughly corresponding to the maximum of nerve density. The other extreme (third type) represents a condenser microphone whose noise spectrum level is inversely proportional to the square of frequency. In spite of this large predominance of the lower frequencies, the essential part of the auditory pattern is still the range between about 700 and 5000 cps. The second type is a piezoelectric sound cell microphone whose noise spectrum lies between the two other types. In no case have the frequencies below, say, 500 cps any bearing on the noise problem, while the contribution of the part above, say, 5000 cps is, in general, important.

The physical reason why microphone noise becomes a practical problem lies in the extremely poor efficiency of microphones, especially high-fidelity ones, as electroacoustical power transducers. The spectral efficiency of a microphone is essentially represented by the inverse square of the ratio of the resistive part of its electrical re-

sistance to reflected acoustic radiation resistance ("useful resistance").\* Practically all "passive" microphones are far remote from ideality: their useful resistance is only a minute fraction of their total resistance, except perhaps for the highest frequencies. Fortunately, the practical requirements concerning microphone noise are extremely liberal: the nuisance level lies several orders of magnitude above the natural noise limit which corresponds to 100 per cent efficiency. This is partly due to the fact that the threshold of hearing is actually above the natural limit; thus a considerable deviation of a microphone from ideality would still be imperceptible. While this deviation amounts to a spectral efficiency of  $-5$  to  $-10$  db in the frequency range of most acute hearing, it is much higher at medium and especially low frequencies, owing to the rapid decrease of ear sensitivity. Therefore it is advantageous to shift the bulk of the noise spectrum of a microphone to low frequencies; this gives, for the same integral noise level, a lower Absolute Noise Level. The predominantly reactive (capacitive) microphones which have this property have thus, other things being equal, an inherent advantage regarding noise performance, as compared with the predominantly resistive types. The noise spectra and auditory patterns of Fig. 1 may serve as an illustration.

The practical nuisance limit for microphone noise is still considerably above the perception limit, owing to the ever-present ambient noise. Excepting special conditions created for acoustical measurements, the loudness level of ambient noise in a "quiet" locality is hardly ever less than about 20 phon (corresponding to a 1000-cps tone of 20-db intensity level). In studio practice, this amount of total background noise would represent extremely favorable conditions: *e. g.*, it would not impose any limitations on the transmission of the full dynamic orchestral range of about 60 db at natural level. Thus, the noise performance of a microphone having an Absolute Noise Level of about 20 phon must be considered as highly satisfactory. For ordinary broadcasting and sound-film purposes, where the dynamic range is limited to 30 to 40 db, an Absolute Noise Level of 30 phon will usually be sufficient.

When discussing various types of microphones as to their noise performance and the factors and limitations on which it depends, care must be taken not to divorce it from general performance; *i. e.*, the former must not be boosted at the expense of other properties.

\* For a more detailed discussion of microphone efficiency, see refs. 1 and 6.

For instance, a reduction of inherent noise can, in general, be achieved by simply increasing the physical size of a microphone; this, however, leads to deterioration of the fidelity and directivity properties. It is mainly for this reason that the noise problem becomes acute only in case of high-fidelity microphones.

Improvement of noise performance is brought about by decreasing the proportion of the "useless" part of the resistive component of the electrical impedance of the microphone circuit, weighted according to the properties of aural perception, without interfering with the quality of acoustical performance. The possibilities of improvement can be grouped in two categories: those dealing with the design of the microphone itself, and those concerning the associated electrical circuits. The possibilities of the second group which are inherently simple will be taken up first. They aim at the "most effective" operation of a given microphone by avoiding additional losses in the electrical circuit and by keeping accessory noises sufficiently below the level of the microphone noise. Barring trivial sources such as hum pick-up, the only additional noise source of importance is the shot noise of the first tube. There are, in general, no principal limitations to the full realization of the inherent noise performance of a microphone when the associated circuits are accordingly designed. Some examples might prove helpful.

If a predominantly resistive microphone, *i. e.*, one of the electrodynamic type, is terminated with its matching resistance, its noise spectrum level is 3 db higher<sup>1</sup> than when it is connected directly to the grid of the first tube (leaving the consideration of tube noise for later). The corresponding increment of Absolute Noise Level will depend in a complicated way on both the spectrum and the level of the noise. It has been found,<sup>1</sup> however, that the empirical relation

$$\text{Increment of Absolute Noise Level} \approx \frac{3}{2} \times \text{Increment of Noise Spectrum Level} \quad (2)$$

holds, approximately,\* for most practical cases, *i. e.*, for the noise

\* The maximum error connected with 2 is about  $1\frac{1}{2}$  phon for increments  $|\Delta B|$  not exceeding about 15 db. This error is in keeping with the limit of accuracy with which Absolute Noise Levels can be determined. A slight correction of the factor  $\frac{3}{2}$  will further reduce the error in case the general character of the noise spectrum (*i. e.*, for flat response of the resistance spectrum) is known: for a "straight" spectrum (Fig. 1; electrodynamic microphones) the factor is about 1.4; for a spectrum proportional to  $f^{-2}$  (as in case of condenser microphones), about 1.6, while it has been found that for piezoelectric sound cells which are intermediate regarding their noise spectrum, the relation 2 holds for increments of  $B$  as high as 20 db with negligible error.



spectra met in the usual microphone types and for the range of Absolute Noise Levels between about 20 and 40 phon. The relation (2) allows a quick appraisal of the effect of electrical and other changes on the noise performance by obviating the repetition of the whole conversion process. It is thus seen that resistance matching of an electrodynamic microphone involves an increase of Absolute Noise Level of 4 to  $4\frac{1}{2}$  phon.\* It follows likewise that, *ceteris paribus*, doubling of the total leakage resistance in a condenser microphone circuit will result in a decrease of noise by  $4\frac{1}{2}$  to 5 phon.\* Similarly, the Absolute Noise Level of a microphone consisting of  $N$  stacked piezoelectric sound cells is  $15 \cdot \log N$  phon below that of a single cell. That this result is independent of the mode of interconnection (so long as it is symmetrical), follows from the physical concept of the noise spectrum level or by direct application of (1).

Optimum noise operation evidently requires that the shot noise level of the first tube be kept sufficiently below the thermal noise of the microphone. This becomes irrelevant for those spectrum components which do not give any important contribution to the perceived noise, *e. g.*, for the frequency range below, say, 700 cps (Fig. 1). It is well known that tube noise can be expressed by an "equivalent noise resistance"  $r_e$ <sup>7</sup> in the grid circuit. The equivalent resistance of triodes operated under full space-charge limitation is

$$r_e \doteq 3 \left( 1 - \frac{\pi}{4} \right) \frac{\theta}{\sigma g} \doteq \frac{2\frac{1}{2} \text{ to } 5}{g} \text{ in most practical cases}^{7,8} \quad (3)$$

$\theta$  = ratio of operating cathode to room temperature;  $g$  = transconductance;  $\sigma$  = factor depending on tube geometry, usually between 0.5 (low- $\mu$  tubes) and 1 (high- $\mu$  tubes).

For most commercial triodes,  $r_e$  is of the order of 1 to 10  $K\Omega$ , for pentodes, 3 to 40  $K\Omega$ .\*\*

For electrodynamic, especially for ribbon microphones, a considerable impedance step-up which is necessary from the point of response level is thus required from the point of noise performance alone.

\* This relates to the same footnote as that on 653.

\*\* For pentodes of conventional construction (*i. e.*, without application of electrooptical principles)  $r_e$  is several times larger than (3), owing to the fact that the "distribution shot noise" between screen grid and plate is not reduced by space charge; therefore the expression for  $r_e$  contains an additional term which is proportional to the plate current and monotonically dependent on the current distribution ratio.<sup>8</sup>



The well known limitations are essentially given by transformer design. Similarly, in the case of capacitive, especially of composite piezoelectric microphones, it is beneficial from the point of both noise performance and response level, to connect as many elements as possible in series. This, however, introduces practical difficulties. The impedance of a piezoelectric sound cell element is mainly capacitive with a small loss angle that varies somewhat, but slowly, with frequency. Therefore, the resistive component  $r_m$  is smallest at the highest frequencies, *i. e.*, it is sufficient to apply the condition  $r_m > r_e$  to the upper end of the useful frequency range, or of the im-

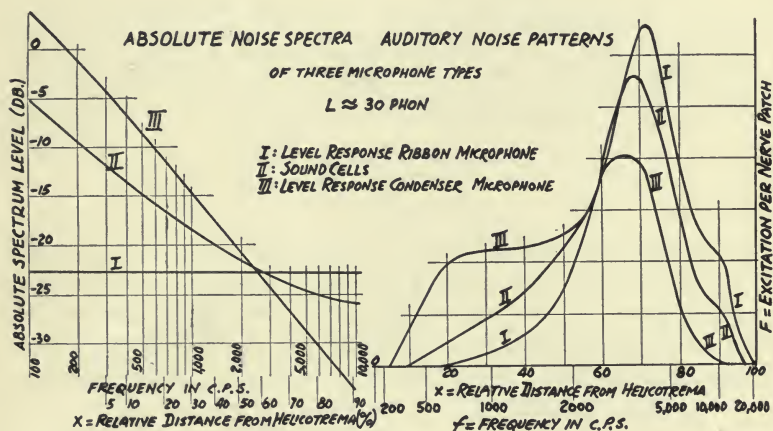


FIG. 1. Noise spectra and auditory patterns of different microphone type.

portant part of the auditory noise pattern (Fig. 1), whichever is lower. The resistive component of the smallest commercial type of sound cell, *i. e.*, that with the largest frequency range (Brush "standard" cell<sup>9</sup>) is between about 2.3 and 6  $K\Omega$  at 10 kc, while its nominal capacity varies between 370 and 730  $\mu\mu F$  between 15° and 30°C (the minimum resistance and maximum capacity occurring at about 23 $\frac{1}{2}$ °C). In a sound cell microphone consisting, *e. g.*, of eight standard cells, all the elements should therefore be connected in series, as in the next possible combination: 4  $\times$  2, which has twice the impedance of the single unit, the condition  $r_m > r_e$  would not be fulfilled, especially with a pentode input. On the other hand, the impedance of the combination 8  $\times$  1 becomes very high at low frequencies: between 50 and 60 megohms at 60 cps and 30°C. The small leakage

thus required for low-frequency response introduces insulation difficulties in the microphone circuit and especially in the tube circuit where a grid leak must be provided for biasing.

This difficulty is not peculiar to the chosen numerical example but is typical for the design of minimum noise circuits for capacitive microphones. It can be overcome by the application of negative

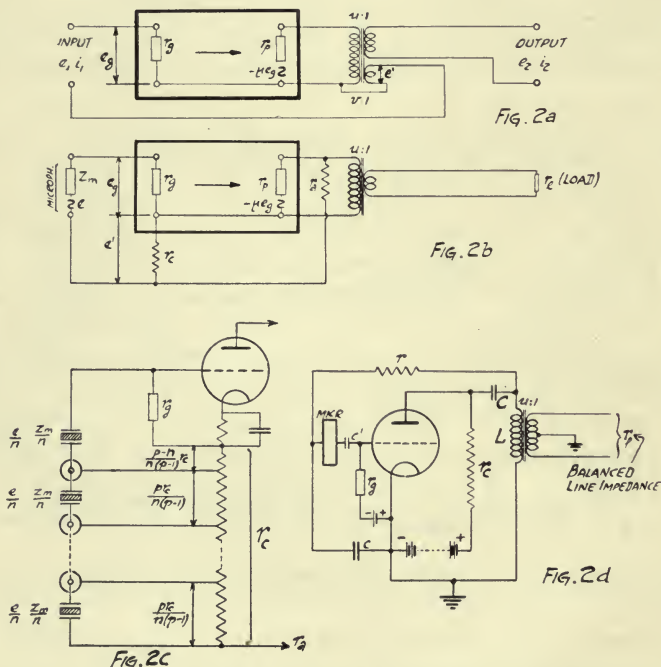


FIG. 2. Negative feedback circuits for impedance transformation.

“series input, parallel output” feedback, which converts the role of the amplifier partly or totally into that of an impedance transformer. The principle of the circuit is given in Fig. 2(a). The amplifier element which may consist of one or several stages, has the amplification factor  $-\mu^*$  and the input resistance  $r_g$  and output resistance  $r_p$  which represent, essentially, the grid leak of the first, and plate resistance of the last tube, respectively. The coupling to the load and the feed-

\* Regarding the sign, see <sup>10</sup>.

back are performed by an ideal transformer with the ratios  $u:1$  and  $v:1$ .

As shown in the appendix, the feedback effects an impedance transformation in the ratio  $p^2$ ; *i. e.*, the input resistance is boosted by a factor  $p$  while both output resistance and voltage amplification are reduced by the same factor. These relations hold for matching loads in both input and output. The transformation ratio  $p$  is, approximately,

$$p = v^{-1} \frac{\mu}{2} + 1 \quad (4)$$

The effect of the circuit is understood when bearing in mind that only the  $p^{\text{th}}$  part of the input voltage  $e_1$  forms the input voltage  $e_g$  of the amplifier while the remaining part  $e' = (p-1) \cdot e_1/p$  is supplied by the feedback. The feedback necessary for satisfactory low-frequency response is

$$p = \frac{1}{2\pi f_e C_m \cdot r_g} \quad (5)$$

where  $C_m$  denotes the minimal capacity of the piezoelectric microphone unit,  $r_g$  the highest permissible grid leak resistance, and  $f_e$  the lower end of the frequency range as characterized by 3-db loss. Fig. 2(b), in which the feedback winding ratio is replaced by a resistance potentiometer  $r_a$ ,  $r_c^*$  shows the arrangement with the microphone with the emf  $e$  and the impedance  $z_m \approx 1/j\omega C$  in the input and a load resistance  $r_e$  with the corresponding matching ratio  $u$  in the output.

While the difficulty of grid insulation is thus eliminated, there remains that of circuit insulation: if the capacitive microphone consists of  $n$  series-connected units of capacity  $C$ , say, with high internal insulation of the individual, the overall leakage of the external mounting structure should be  $< \omega_e C/n$ . As shown, this may call for insulations that can not safely be maintained. This difficulty can be overcome by making use of the feedback voltage  $e' = (p-1) \cdot e_1/p$  (see Figs. 2(a) and 2(b)) which provides points at the cathode resistor  $r_c$  having the potentials  $ke/n$ ;  $k = 1, 2, \dots, (n-1)$  with respect to the low end. External leakage is eliminated by connecting these points to guard-rings surrounding the connections between the microphone

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\* This holds for  $\mu > 0$ , *i. e.*, an odd number of stages; for an even number, the connections must be interchanged. In almost all practical cases the value of the potentiometer resistors can be chosen in such a way that both the loss of gain and increase of thermal noise as compared with the transformer coupling are negligible.

units which are held by the mounting structure, as indicated in Fig. 2(c).<sup>\*</sup> The location of the taps is  $kp/n(p-1) \cdot r_c$ ;  $k = 1, 2, \dots, (n-1)$ .

The practical application of this preamplifier circuit to reactive high-impedance microphones obviously calls for short connections between microphone and amplifier input. A practical solution for the usual arrangement of movable microphone and stationary amplifier is then to divorce the functions of impedance transformation and amplification by performing the former with a single midget tube incorporated into the microphone, with the associated supplies and those accessories that do not require short connections, located at the base of the microphone stand. This arrangement was successfully employed in an experimental model of a unidirectional microphone consisting of a composite sound-cell unit and a velocity-type ribbon unit, which was designed for full exploitation of the inherent noise performance. The tube used for the transformation from the high-impedance microphone to a 200 or 500-ohm line was a Raytheon hearing-aid type *CK502X* in triode connection; it has a diameter of  $\frac{4}{16}$  inch, is  $1\frac{1}{2}$  inches high, weighs less than 8 grams, and requires a filament power of only  $\frac{1}{25}$  watt. The feedback circuit reduces to a simple circuit related to the well known "cathode follower" ( $v = 1$  in Fig. 2(a),  $r_a = 0$  in Fig. 2(b)) with

$$p = \frac{\mu}{2} + 1 \quad (6)$$

according to (4). The actual circuit used is given in Fig. 2(d). It incorporates some refinements. The return connection is made to the output transformer instead of the plate, which has the double advantage of keeping the d-c plate voltage from the microphone where it might cause leakage under high humidity, and of decreasing the size of the condenser  $C$  necessary for low-frequency performance. The resistance  $r_c$  merely serves as d-c plate supply and should be made as high as possible. The value required for the transformer inductance  $L$  is considerably reduced due to output impedance reduction through feedback (Appendix;  $f$ ). The small resistor  $r$  and condenser  $c$  boost the response at high frequencies and thus compensate the drop of the ribbon response; this effect is due to the associated

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<sup>\*</sup> This idea was suggested by Mr. W. J. Brown of The Brush Development Company.



redistribution of feedback and gain. The value of  $r$  is so small that its additional thermal noise is negligible.

As the noise spectra of ribbon and piezoelectric microphones have very different shapes, as seen from Fig. 1, it seems necessary to compute the Absolute Noise Level of the unidirectional combination by the conversion process. An approximate result can be obtained, however, by simply taking into account the decrement of noise spectrum level in the most important part around 4 kc and applying the incremental rule 2. In our case, where the noise performance of the sound-cell component is definitely superior to that of the ribbon, this

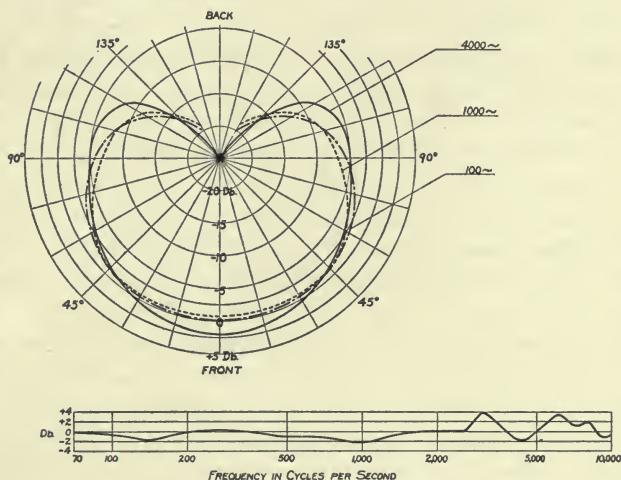


FIG. 3. Response of unidirectional microphone.

method is particularly well applicable. If the relative noise contribution of the piezoelectric part were entirely negligible, the Absolute Noise Level of the unidirectional combination should be 9 phon lower than that of the ribbon alone. In the experimental model, the actual improvement was about 6 phon, partly due to residual tube and circuit noises. The front response curve and polar diagrams for three different frequencies of the microphone in the unidirectional combination are shown in Fig. 3.\*

Discussion has so far been restricted to such possibilities of noise

\* Messrs. D. Domizi and S. Carpenter were active in the development and testing of the experimental microphone unit.

improvement as deal with the associated circuits and serve to realize the inherent noise performance of a given microphone to the full extent. As mentioned in the beginning, this performance depends on the proportion of the "useful" part in the total microphone resistance. The possibilities of increasing this part through the design of the microphone itself may roughly be subdivided into three classes: those that aim at increasing the electromechanical coupling, and those that aim at reducing the "dead" losses on the electrical and on the acoustical side of the microphone, respectively. They are frequently interconnected as well as dependent upon the general acoustic performance and cover a rather wide field, with different kinds of limitations. No attempt is made here to treat them exhaustively. Likewise, a quantitative comparison of the ultimate practical limits of noise performance of the different microphone types is difficult and possibly premature. There are, however, several simple principles of noise reduction and clear merits and weaknesses of the different types.

Simple cases of dependence of noise performance on electromechanical coupling alone are realized in the electrodynamic and condenser types. In the former case, it is the magnetic field; in the latter, the polarizing voltage, to which the coupling factor  $k$  is proportional. Its influence can be described in two equivalent ways: the response is proportional to the coupling, the reflected resistance, to its square; both mean that the noise spectrum level decreases with  $-20 \cdot \log k$ , *i. e.*, the Absolute Noise Level approximately with  $-30 \cdot \log k$ . It is due to the difference in coupling arising from the dimensions of the magnetic circuit that among the electrodynamic types, the moving-coil microphone has a considerably higher efficiency, *i. e.*, lower Absolute Noise Level, than the ribbon. The difference amounts to about 10–15 phon in typical cases.<sup>1</sup> In the case of piezoelectric microphones, the electromechanical coupling is inherently fixed and depends upon the piezoelectric modulus  $f$  connecting electric field with stress in the direct, and strain with dielectric polarization in the inverse effect. We mention that, in the case of Rochelle salt, which is the only material that so far has been put to microphonic use on a commercial scale, the corresponding modulus  $f_{14}$  does not show any temperature anomaly,<sup>15, 16</sup> as it is often wrongly assumed; the temperature anomaly is strictly confined to the dielectric behavior of the "clamped" lattice and probably due to a molecular transition.<sup>16</sup> The value of  $f_{14}$  is about  $2 \times 10^7$  volts-cm<sup>-1</sup>.<sup>15, 16</sup>

Microphone noise is increased by "useless" resistive components on both the mechanical and electrical side. In most cases, no material improvements are possible on the electrical side: *e. g.*, in the case of electrodynamic microphones, this would call for materials of higher ratio of electrical conductivity to density; in the case of condenser microphones, for excessively high leakage insulation. On the mechanical side, things are different. For instance, the pressure-operated electrodynamic microphone should be resistance-controlled for flat response. If this control were achieved by introducing sufficient mechanical damping to suppress stiffness and inertia control, the result would be disastrous. Instead, as is well known, the method of approximate reactance compensation by acoustical multi-section networks is applied,<sup>17</sup> which results in a good noise performance and high response level.\* In the case of the high-fidelity piezoelectric sound cells available at the present time, about 50 to 75 per cent of the losses are due to the mounting materials, and a considerable part of the remainder, probably to the cement and coating of the bimorph<sup>18</sup> elements. A new type of microphone unit is being developed which, beside other features, avoids damping materials and tends to reduce the losses and to adjust their spectral distribution as favorably as possible.

Noise performance is most effectively boosted by measures that lead to an increase of response level without offsetting it by a corresponding increase of "dead" losses, and without impairing the acoustical performance. It was mentioned previously that, in general, noise performance improves with the physical size of the microphone, which, however, is limited by natural frequencies and sound-field effects, to a degree determined by the required acoustical quality. By suitable choice of materials and mechanical design, it is often possible to make the former restriction less stringent than the latter which alone represents a principal limitation. The sound-field effects are determined, not by the active part of the microphone alone, but by its overall size, including necessary auxiliary structures. Furthermore, the corresponding limitation regarding size is not materially different for different "regular" shapes. Therefore, noise

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\* As even in this way a considerable amount of additional resistance is introduced into the acoustical circuit, the noise performance could theoretically be further boosted by performing the frequency correction electrically after pre-amplification; this, of course, is not a practically acceptable solution.



performance can be boosted most effectively by increasing the "spatial efficiency." This possibility is severely limited in the case of electrodynamic microphones because of both the required proximity of relatively large auxiliary structures, and the restriction to an essentially two-dimensional extension of the active part. In the case of the velocity ribbon, this is implied in the pressure-gradient operation. In the case of the pressure-operated types, it is due to the fact that they are not stiffness controlled, *i. e.*, have relatively small and frequency-dependent stiffness; therefore an excessive mutual influence and thus no material increase of response would result from crowding such elements into a space of approximately equal extension in the three dimensions. For piezoelectric sound cells, conditions are totally different. They are pressure-operated and stiffness-controlled for flat response. As a matter of fact, because of the very high stiffness of the material, the impedance mismatch to air amounts to 4 orders of magnitude and, in general, would rule out any effective use as microphone (as an "expander" type) because of small response, were it not for the application of the bimorph combination<sup>18</sup> which gives a mechanical advantage of 1 to 2 orders of magnitude. There is still enough margin left for "stacking" a number of cells which make up one microphone unit, with negligible mutual influence, thus making use of all three dimensions of space.\* Furthermore, the impedance of such microphones is not excessively high, *i. e.*, much lower than that of corresponding condenser types, because of the high dielectric susceptibility of Rochelle salt. This permits reasonable length for connections and thus does not require the proximity of large auxiliary structures like stationary amplifiers. This high spatial efficiency of piezoelectric microphones, together with the favorable distribution of their noise spectrum, makes them particularly adaptable to low-noise high-fidelity operation. In the commercially available sound cells, the possibilities of low-noise performance are not yet fully realized. This is not only due to the losses in damping materials, but also to the mechanical construction involving, among other things, a considerable amount of inactive frame surface and diaphragm instead of piston action. The new developmental unit previously mentioned is designed along new lines and comes much

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\* It should be possible to stack double-acting condenser microphone elements in a similar way and thus to arrive at highly efficient units. The idea was suggested by one of the writers.<sup>19</sup>



nearest to a realization of the potential efficiency of the piezoelectric microphone. Its response level is about 10 db higher, and its impedance, about one-half that of the "standard" sound cell. There is also probably a marked decrease of loss angle. Preliminary estimates taking into account the increased size of the unit make it seem possible to attain, with microphones made up of these units, the goal set by the most exacting requirements of modern high-fidelity communication: a frequency range up to about 13 kc simultaneously with an Absolute Noise Level of 20 phon.

#### APPENDIX

A simplified and abbreviated derivation of the property of the applied feedback circuit as impedance changer is given. The impedance changes effected by different modes of feedback are generally discussed in<sup>11</sup>; see also<sup>12</sup>. The present derivation presupposes an "ideal transformer," and does not take into account the conditions at the lower and upper ends of the useful frequency range, which may be easily accounted for. In this connection, we quote<sup>13</sup> and, more generally,<sup>14</sup>

With no feedback ( $v^{-1} = 0$ ), the input impedance of the circuit is  $r_g$ , the output impedance,  $u^{-2}r_p$  and the voltage gain

$$\frac{e_2}{e_1} \equiv G = \sqrt{\frac{r_1}{r_p}} \cdot \frac{\mu}{2} \equiv G_0 \quad (a)$$

for the load resistance  $r_1$  and the matching ratio

$$u = \sqrt{\frac{r_p}{r_1}} \quad (b)$$

With feedback, the equations of the quadripole are

$$e_1 = \{(v^{-1}\mu + 1)r_g + v^{-2}r_p\}i_1 + u^{-1}v^{-1}r_p i_2$$

$$e_2 = \{u^{-1}\mu r_g + u^{-1}v^{-1}r_p\}i_1 + u^{-2}r_p i_2$$

Considering that  $r_p \gg r_g$  in all practical cases, it follows that upon loading the output by  $r_e$ , the input resistance becomes

$$\left(\frac{e_1}{i_1}\right)_{e_2+r_e i_2=0} \doteq \left(\frac{v^{-1}\mu}{1 + u^{-2}\frac{r_p}{r_1}} + 1\right)r_g \equiv p \cdot r_g \quad (c)$$

i. e., it is multiplied by the factor  $p$  through the application of feedback. For the previous matching ratio (b) we obtain

$$p = v^{-1}\frac{\mu}{2} + 1 \quad (d); \quad (\frac{1}{2} \text{ in text})$$

The voltage gain of the system is now

$$G \doteq \frac{\mu}{2} \sqrt{\frac{r_1}{r_p}} \left\{ v^{-1}\frac{\mu}{2} + 1 \right\}^{-1} = \frac{G_0}{p} \quad (e)$$

as seen from  $a$  and  $d$ ; the loss of voltage amplification equals the "input impedance amplification." At the same time, the output resistance for the primary load  $r_o$  becomes

$$\left(\frac{e_2}{i_2}\right)_{e_1 + r_{o1}} = 0 \frac{r_e}{p} \quad (f)$$

which means that the application of the feedback is equivalent to an impedance transformation.

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## NEW MOTION PICTURE APPARATUS

*During the Conventions of the Society, symposiums on new motion picture apparatus are held in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.*

### TEMPERATURE CONTROLLED DISK RECORDING CUTTER\*

S. J. BEGUN\*\*

To attain best results in any sound system consisting of a number of elements, it is necessary to know the characteristic of any individual unit involved in the transmission chain and to make provision for proper compensation of the deficiencies inherent in that unit. Difficulties are encountered, however, as soon as such elements involved in the system do not have stable characteristics, but change, for some reason, during the time of operation. From this, it is quite evident that a high-fidelity sound-recording system requires that each element used in the recording chain must possess a definite and stable characteristic.

It has been found that a change of temperature affects the performance of two of the important elements in the recording process: one of these elements is the cutting device, and the other is the disk material. Due to the realization that temperature changes are detrimental to the proper performance control of the system, most studios (certainly the better ones) nowadays are air-conditioned to keep the temperature constant, within narrow limits, in the room where the recording is made. However, even with this precaution, difficulties present themselves, particularly with magnetic cutters which at present represent the majority of cutting devices used for high-fidelity recording. One reason for these difficulties is that a magnetic cutter converts a considerable part of the energy supplied to it into heat, causing, after a certain period of operation, a warming-up of the cutter, resulting in a change of the characteristics of the device. As a matter of fact, this internal heating of the magnetic cutter is of such importance that some cutters are deliberately constructed much more massively than is required from mechanical considerations, in order that the added metal may increase the thermal capacity of the cutter and make it possible for more heat energy to be absorbed without too greatly raising the temperature. The added metal also provides more heat radiating area.

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\* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received October 13, 1940.

\*\* The Brush Development Co., Cleveland, Ohio.



The purpose of this paper is to discuss in a general way the effect of temperature upon magnetic, as well as upon crystal cutting devices. The discussion will be limited to these two methods for converting electrical into mechanical energy since, to the knowledge of the writer, no other principle, to date, has been recommended for such purpose. Furthermore, it is the aim of the paper to show that a crystal cutter can be constructed which, in its performance, is rather independent of the temperature of the recording room, and is thus capable of overcoming one of the most important difficulties pointed out above.

Let us first investigate, in a more general way why cutter characteristics are dependent upon temperature. For this investigation it is very useful to distinguish between the two essential elements in every cutter; these are the damping material used in the cutter and the motor system employed to drive the cutter stylus.

To understand better the relative importance of the different components in the cutting system, it is convenient to draw a simple analogy (Fig. 1): Assuming that the chuck and the stylus are rigid and well connected to the driving system, we can visualize an electrical generator of zero impedance which represents the mechanical force. This generator has to work into the following elements connected in series: a condenser, representing the compliance (the inverse of stiffness) of the vibratory system; an inductance, representing the mass of the moving parts; a resistance, representing the internal damping; and another resistance, representing the external damping. In such a representation, the stylus motion will be equivalent to the charge. This picture, while only symbolic, will, however, explain the significance of the various components which load the mechanical displacement of the cutter.

Now, let us scrutinize these different components from the standpoint of stability in cutting a record. The one resistance component, which represents the energy dissipated in the cutting process, is obviously not constant. It will depend upon the depth of cut, the record material used, and other considerations. The other resistance component also, representing the internal damping, is not constant. Oil, rubber, neoprene, koroseal, viscoloid, or other viscous materials are generally used for this internal damping. Unfortunately, it is extremely difficult, if not impossible, for the time being, to find any damping material the internal friction of which does not change with temperature, and that does not have a certain amount of hysteresis and cold-flow.

Furthermore, the stiffness represented by the condenser in many cases varies too, since the damping material may be used to some extent to increase the stiffness of the armature. In addition, these damping materials have non-linear resistive and capacitive components, and can introduce undesirable distortions.

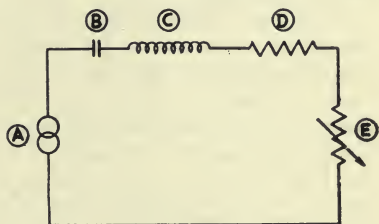


FIG. 1. Electrical analogue of representative cutter. *A*, generator. *B*, stiffness of cutter mechanism (may not be linear). *C*, mass of moving parts of cutter. *D*, internal damping (may not be linear). *E*, external damping including work done by cutting process.

Finally, we may arrive at the conclusion that the only stable impedance in a cutter is represented by the inductance, or the mass of the moving parts, which is not likely to change during the cutting process.

Because of all these variables it is almost impossible to expect that the performance of a cutter can be foretold. On the other hand, if we can eliminate a number of variables and make the impedance of the remaining variables small compared to the impedance of the stabilized circuit components, the performance characteristic will, in general, vary only within extremely narrow limits.

Experiments indicate that this can be done by keeping the temperature of the cutter constant, since such constant temperature will stabilize the characteristic of all the variables inside the cutter, thus leaving the external resistance component as the only variable, representing the variations due to depth of cut and differences in record material. If this remaining variable-resistance component, for the frequency range considered, is small in comparison with any of the other three components, it obviously has little control upon the characteristics of the cutter as a whole.

But let us consider certain other important aspects. Assuming that the external load due to the cutting process is negligibly small, so that for the moment it may be neglected, the next circuit element of importance is doubtless the resistance representing the damping. If this resistance happens to be non-linear—and most of the damping materials, particularly at low frequencies, are, unfortunately, non-linear—it is important that this resistance should not have a controlling influence upon the performance of the cutter, especially in the low-frequency range. For low frequencies, the cutter is stiffness-controlled, meaning that the impedance represented by the condenser in our symbolic circuit has a major controlling influence. However, if the stiffness of the cutter is to a large extent provided also by the damping material, with its non-linear characteristic, the effect of the damping will be disagreeable. Furthermore, if the ratio of stiffness to inertia of the system is such that the cutter will resonate at low frequencies where only the frictional component of the damping material exercises the necessary control, considerable distortion must be expected as a result.

This is one important reason why the designer of a good cutter must see to it that the resonance frequency of the device is as high as possible, or, to express it in other words, that the stiffness controls the cutter over as wide a range as possible; and furthermore, that this stiffness be an ideal stiffness and not change with amplitude.

It follows, therefore, coming back to our symbolic circuit, that if we can keep the stiffness of the circuit constant with respect to amplitude and also have this stiffness represent an impedance value much higher over a great part of the range than the resistive component of the damping material, we should be able to obtain an exceedingly stable cutter. These considerations led to the design of a temperature-controlled cutter, the temperature of the cutter being maintained constant within narrow limits.

A magnetic cutter consists essentially of an armature moving in a magnetic field created by a permanent magnet. This armature is connected to a chuck, and the whole moving part is thoroughly secured by damping materials. The activating coils are wound about the armature. This essential design of a magnetic cutter is shown in Fig. 2.

The magnetic motor, including the permanent magnet field and the armature is not affected by temperature variation within practical operating limits. Unfortunately, however, we must consider also the influence of the damping upon the magnetic cutter. Most of the cutters now available have the resonance fre-

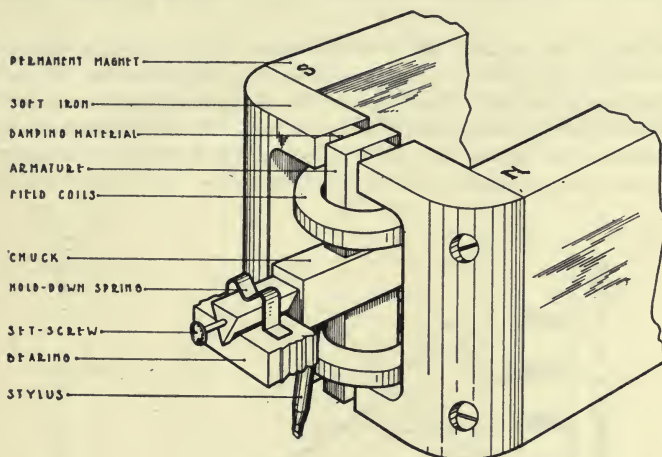


FIG. 2. Representative magnetic cutter.

quency of the system inside the useful range, particularly when the range must extend as low as 30 cycles and as high as 10,000 cycles. Since peaks should be eliminated to assure satisfactory performance, damping material must be provided that will sufficiently attenuate the resonance peak of the system. Due to the fact that the resistive component of the damping material changes with temperature, the sensitivity of the cutter, despite the fact that the motor-driving

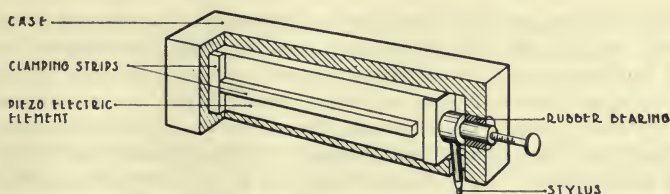


FIG. 3. Representative crystal cutter.

system is not affected by temperature change, may, in its overall performance, be subject to variations with temperature. Furthermore, due to the fact that certain amounts of hysteresis and cold-flow are present, the damping material not only acts as a resistive component, but at the same time, introduces undesirable distortion. Some control of temperature is required if best results are to be obtained from magnetic cutters.



Now consider the crystal cutter. A representative crystal cutter is shown in Fig. 3, and consists mainly of a Rochelle salt bimorph crystal element held firmly on one end to a metal case, but free to move torsionally at its other end. This free end is connected to a chuck, which may be provided with a simple bearing to move in the case, or other provision may be made to clamp the stylus rigidly to the chuck.

Electrically, the Rochelle salt crystal element which converts electrical into mechanical energy in the cutter may, to a first approximation, be considered equivalent to a condenser. Furthermore, the mechanical flexure produced by the piezoelectric effect is, within practical limits, proportional to the charge supplied to the crystal. This means that the sensitivity of the Rochelle salt element, when expressed as a ratio of flexure to electrical charge, is not a function of temperature.

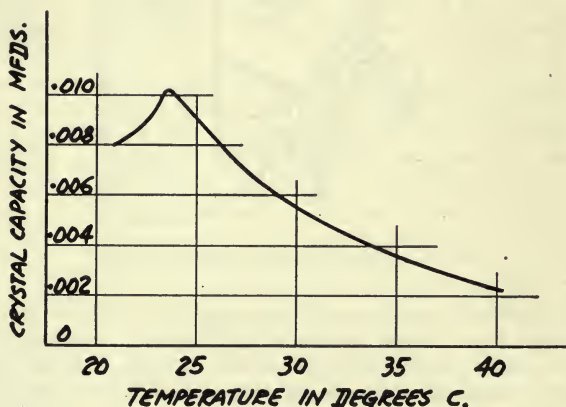


FIG. 4. Crystal cutter capacity vs. temperature.

But while it is true that the charge-flexure relation is not a function of temperature, it is, on the other hand, true that the voltage-flexure relationship is a function of temperature, and since crystal cutters are normally used in constant-voltage systems, rather than in constant-charge systems, it is unfortunate that the crystal element characteristic usually varies somewhat with temperature.

In Fig. 4, the capacity of a crystal element in such a cutter is shown as a function of temperature. The capacity is highest in the neighborhood of 23.5°C, and less at lower and higher temperatures. Since the charge is equal to the product of capacity and voltage, the sensitivity, for a given applied voltage, will be highest at this critical temperature, which is generally identified as the Curie point. From this curve, we can assume that with approximately 35°C, the sensitivity of the crystal element, referring to the same terminal voltage, will be reduced approximately 9 db. This reduction in sensitivity, so far as the cutter is concerned, is theoretical. The actual measured reduction in sensitivity of the complete cutter is less, being about 6 db between 23.5° and 35°C. These variations of sensitivity, while not objectionable, when such a cutter is used for home



recording, will be rather objectionable if it is made part of a high-fidelity sound recording channel.

As has been pointed out, the temperature effect may be eliminated by applying a constant charge to the crystal element. As a matter of fact, a circuit can be designed that will supply the cutter with a charge varying with the input voltage to the amplifier, and the simplest way of accomplishing this is to connect in series with the cutter a condenser having a capacity of the same order as, or slightly lower than, the cutter capacity. Due to the fact that now two condensers are connected in series, both of the same order of magnitude, one condenser being electrically independent of temperature, and the other somewhat de-

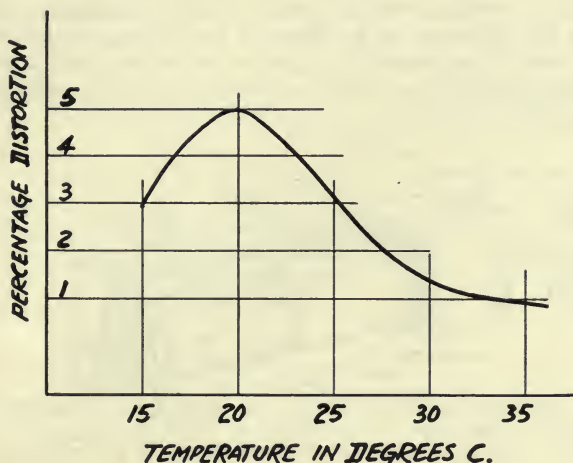


FIG. 5. Crystal cutter distortion vs. temperature.

$$\text{Percentage Distortion} = 100 \frac{\sqrt{E_2^2 + E_3^2}}{E_1} \text{ where } E_1 =$$

Fundamental,  $E_2$  = 2nd Harmonic,  $E_3$  = 3rd Harmonic.

Amplitude, 0.7 mil; cutter voltage, 100 v; frequency, 400 cycles.

pendent upon temperature, the electrical charge supplied to the crystal element may be kept within somewhat constant limits. While this rather simple method is useful in applications where certain leeway in stability is permitted, such a system will not provide a sufficiently constant performance characteristic to meet the high requirements of a broadcasting or recording studio. More complicated networks may be devised to provide a constant electrical charge to the cutter terminals, but it should not be forgotten that the characteristics of the damping material also change with temperature.

These points all indicate the desirability of maintaining the cutter at a fixed temperature, and proportioning the elements within the cutter for a minimum distortion at that temperature.

The question arises as to what temperature should be selected. Since air-conditioning of the recording room is a rather expensive requirement, the cutter temperature should be higher than the usual room temperature, so that the cutter performance may not be affected by variations of temperature due to climatic conditions. There are other considerations in addition to this which are of great importance. The damping material introduces distortion, as mentioned before, which distortion depends also upon the temperature. Where the design of the cutter depends greatly upon the damping material, the temperature should be chosen at which the damping material introduces a minimum of non-linearity. In the crystal cutter the damping material is not a controlling factor over the major part of the frequency range, but it has been found that the crystal element itself introduces a small amount of distortion which changes with temperature. Fig. 5 shows this distortion, the amplitude of motion being a parameter. The distortion is small at and above  $35^{\circ}\text{C}$ , and for the cutter to be described a temperature of approximately that value has been adopted for purposes of stabilization.

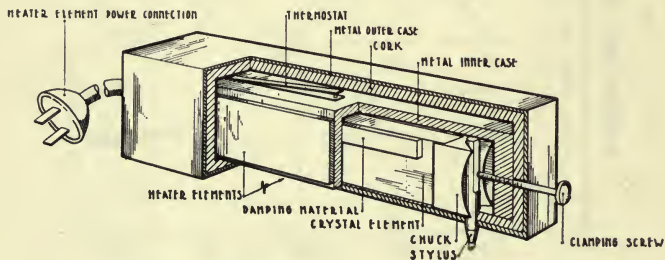


FIG. 6. Representative temperature-controlled crystal cutter.

At this point, the fact should be emphasized that the crystal element does not generate much heat in operation; nearly all the heat produced in a crystal cutter is generated by the damping material. However, experience has shown that even during long periods of operation, the temperature of a crystal cutter is not increased by the inherent damping losses, thus making it simple to stabilize the temperature of such a device.

Fig. 6 shows the assembly of a temperature-controlled cutter. A four-ply crystal element is mounted in a metal casing on koroseal pads. These koroseal pads represent the damping, and not only provide a very stiff mounting support, but, because of their damping characteristic, practically eliminate the peak of the natural frequency of the cutter. The stylus chuck is connected to one end of the crystal element. This chuck has a V-groove bent into the form of an arc, thus permitting the stylus to rest upon two points. The stylus is pressed against the V-groove by means of the set-screw mounted in the cutter casing. The axis of the set-screw is located on the neutral axis of the torsional motion of the crystal element. The set-screw does not participate in the motion of the stylus, thus eliminating the bearings usually found in other cutter designs. This construction reduces somewhat the inertia of the moving system.

The chuck, as described above, has been shaped so as to afford the stylus a long support. Experiments have indicated that many commercial styli have a tendency to break up when cutting higher frequencies if not supported over a large part of their length.

Two heating pads are mounted close to the cutter housing sidewalls, controlled by a thermostat which rests upon and has good metallic connection to the cutter housing. It is important that the thermostat and the cutter housing be connected by means of a good heat-conducting path. For simplicity, the heater coils are designed to be operated on the 110-volt line. The complete unit is enclosed in another heat-insulated metal shielding, making it unlikely that any draft or motion of air in the room will affect the temperature stabilization of the crystal cutter inside the housing.

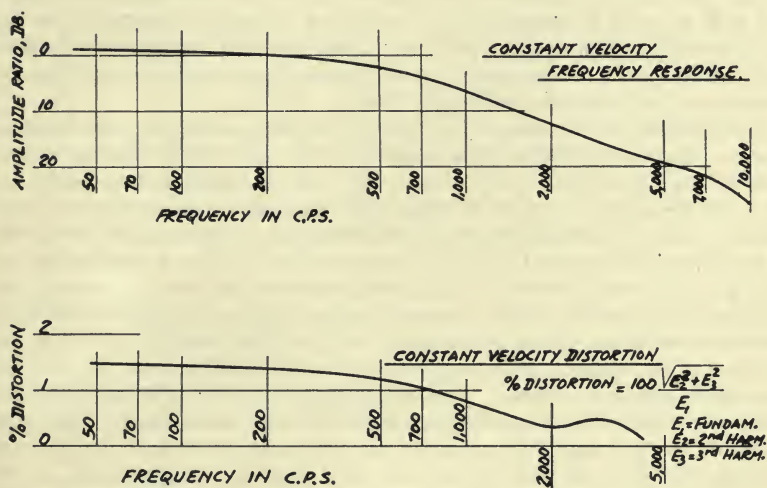


FIG. 7. Response characteristics of temperature-controlled cutter.  
Temperature, 35°C. Amplitude, 1 mil.

After connecting the heater system to the power supply, the temperature of the cutter will rise, and, as a matter of fact, will rise above the temperature limit set for the thermostat. A definite time is required for heat equalization, due to heat conduction, thus causing this temperature over-shooting. But soon the thermostat begins to operate and finally the cutter arrives at the proper temperature. This period of heating-up and adjusting to the proper temperature depends upon the location of the heating elements and thermostat, and the wattage for which the heater coils are wound. In the design shown, the temperature stabilization requires ten or twelve minutes. This does not mean, however, that the cutter may not be used somewhat earlier, since after five minutes the temperature variation will be sufficiently small not to influence the sensitivity of the cutter greatly. There is no danger in keeping the heater elements constantly connected to the power supply.



The question may arise as to whether the current or voltage on the heater terminals will interfere with the operation of the cutter because of the introduction of hum. So far as electrostatic influences are concerned, the cutter is completely shielded in its housing. On the other hand, electromagnetic induction can not take place in the crystal element. All experiments have proved that no hum problems are present.

In Fig. 7, the frequency response curve and the harmonic distortion of such a cutter are shown.

This cutter requires, for 1-mil amplitude, a terminal voltage of approximately 165 volts. Its capacity is  $0.004 \mu f$  and, therefore, to extend the range for constant-amplitude recording to 9000 cycles, the cutter should be fed from an impedance of approximately 4000 ohms. The amplifier, under such a condition, should have available at least 8 watts of output power, but it is rather abnormal to cut with as great an amplitude as 1 mil, using a constant-amplitude recording characteristic. If a constant-velocity characteristic is desired for a turnover point of 500 cycles, the necessary output power required from the amplifier may be as low as 2 or 3 watts for satisfactory results.

Summarizing, the necessity of temperature control in the cutter design has been shown. Furthermore, it has been pointed out that it is highly desirable to provide such stiffness in the cutter construction that the mechanical resonance will be in the upper part of the useful range, and, if possible, even outside the useful range. Since the stiffness impedance will control the performance of the cutter, it is extremely important that it be a linear stiffness, and not introduce any distortion. The crystal element, as the driving motor for the cutter, approaches this desirable characteristic, while a magnetic cutter, inherently not gifted with this natural stiffness, very frequently depends upon damping material to increase the stiffness of the system. However, the stiffness obtained by means of damping material is usually not linear. Formerly, temperature control in studio installations was obtained by expensive and cumbersome air-conditioning. The cutter described has been designed to gain the same desirable effects of this temperature stability by means of a built-in heating element with thermostat control. It will make possible the construction of portable equipment which can now operate with the same stability as studio equipment. It has been a difficult task for the recording companies to make "on-location" recordings. In one case, where recordings were made in South America, the operator of the equipment was forced to burden himself with a dry-ice machine to keep the temperature during the cutting process within the required range. Such a temperature-controlled cutter as described here would do away with such difficulties.



## CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

*The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Biblionfilm Service, Department of Agriculture, Washington, D. C., at prevailing rates.*

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## PROGRAM OF THE SPRING CONVENTION\*

SAGAMORE HOTEL, ROCHESTER, N. Y.

MAY 5-8, 1941

MONDAY, MAY 5th

**9:30 a.m. General Session; H. Griffin, Chairman.**

Report of the Convention Arrangements Committee; W. C. Kunzmann, *Convention Vice-President*.

Report of the Financial Vice-President; A. S. Dickinson.

Report of the Engineering Vice-President; D. E. Hyndman.

Welcome by the President; Emery Huse.

"The University of Minnesota Visual Education Program;" R. A. Kissack, Minneapolis, Minn. (*Demonstration*.)

"Five New Models of 16-Mm Sound Kodascopes;" W. E. Merriman, Eastman Kodak Co., Rochester, N. Y.

"Air-Conditioning Safety Device for Motion Picture Theaters;" E. R. Morin, Motion Picture Division, Connecticut State Police, Hartford, Conn.

"The Specialization of Film Delivery;" J. H. Vickers, National Film Carriers, Inc., Philadelphia, Pa.

**12:30 p.m. Informal Luncheon with Acoustical Society of America**

*Chairman: Emery Huse, President, Society of Motion Picture Engineers.*

*Addresses by:*

The Honorable S. B. Dicker, Mayor of the City of Rochester.

Dr. F. R. Watson, *President*, Acoustical Society of America.

Dr. Howard Hanson, *Director*, Eastman School of Music, University of Rochester, Rochester, N. Y.

**2:00 p.m. Illumination Session; D. B. Joy, Chairman.**

"Characteristics of Intermittent Carbon Arcs;" H. G. MacPherson, R. B. Dull, and F. T. Bowditch, National Carbon Company, Cleveland, Ohio.

"Some Properties of Polished Glass Surfaces;" F. Jones, Bausch & Lomb Optical Co., Rochester, N. Y.

"Recent Improvements in Non-Reflective Lens Coating;" W. Miller, Vard Mechanical Laboratories, Pasadena, Calif.

"A Method for Designing Film Sprockets;" W. G. Hill and C. L. Schaeffer, Agfa Ansco Corp., Binghamton, N. Y.

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\* As actually followed at the meetings.

"Some Theoretical Considerations in the Design of Sprockets for Continuous Film Movement;" J. S. Chandler, Eastman Kodak Co., Rochester, N. Y.

Report of the Non-Theatrical Equipment Committee; J. A. Maurer, *Chairman*.

**8:00 p.m. Sound Session; G. Friedl, Jr., *Chairman*.**

Report of the Standards Committee; D. B. Joy, *Chairman*.

"Multi-Speaker Systems;" H. I. Reiskind, RCA Manufacturing Co., Inc., Indianapolis, Ind.

"Fantasound;" W. Garity and N. A. Hawkins, Walt Disney Studios, Burbank, Calif.

"Vitasound;" N. Levinson and L. T. Goldsmith, Warner Bros.-First National Studios, Burbank, Calif.

"New and Old Aspects of the Origins of 96-Cycle Distortion;" J. O. Baker and R. O. Drew, RCA Manufacturing Co., Inc., Camden, N. J.

**TUESDAY, MAY 6th**

**9:30 a.m. General and Business Session; P. J. Larsen, *Chairman*.**

"High-Fidelity Headphones;" L. J. Anderson, RCA Manufacturing Co., Indianapolis, Ind.

"New Gadgets for the Film Laboratory;" B. Robinson and M. Leshing, Twentieth Century-Fox Film Studios, Hollywood, Calif.

"Report on the Activities of the Inter-Society Color Council;" R. M. Evans, *Chairman* of SMPE Delegates.

**Society Business**

"Some Recent Advances in the Theory of the Photographic Process;" C. E. K. Mees, Eastman Kodak Co., Rochester, N. Y.

**2:00 p.m. Open Afternoon**

**7:30 p.m. 48th Semi-Annual Banquet and Dance.**

**WEDNESDAY, MAY 7th**

*Joint Meeting of the Acoustical Society of America  
and the Society of Motion Picture Engineers*

**9:30 a.m. Eastman Theater; Symposium on the Stereophonic Sound-Film System, by Bell Telephone Laboratories, New York, N. Y. B. Olney, *Chairman*.**

"General Theory;" Harvey Fletcher.

"Mechanical and Optical Equipment;" E. C. Wentz, R. Biddulph, L. A. Elmer, and A. B. Anderson.

"Pre- and Post-Equalization of Compandor Systems;" J. C. Steinberg.

Technical Demonstration; Conducted by W. B. Snow.

*Joint Meeting of the Acoustical Society of America  
and the Society of Motion Picture Engineers*

**2:00 p.m. General Session; J. I. Crabtree, Chairman.**

"Electrical Equipment for the Stereophonic Sound-Film System;"

W. B. Snow and A. R. Soffel.

"A Light-Valve for the Stereophonic Sound-Film System;" E. C.

Wente and R. Biddulph.

"Internally Damped Rollers;" E. C. Wente and A. H. Müller.

"Solar Prominences in Motion;" R. R. McMath, McMath-Hulbert  
Observatory, Lake Angelus, Pontiac, Mich. (*Demonstration.*)

"A Non-Cinching Film-Rewind Machine;" L. A. Elmer.

"Progress in Three-Dimensional Photography;" J. A. Norling,  
Loucks & Norling, New York, N. Y. (*Demonstration.*)

*Joint Meeting of the Acoustical Society of America  
and the Society of Motion Picture Engineers*

**8:15 p.m. Eastman Theater; Demonstration of Stereophonic Sound-Film  
System, by the Bell Telephone Laboratories, New York, N. Y.**

*Chairman:* **Dr. Howard Hanson**, Director of the Eastman School of  
Music, University of Rochester.

*Speakers:*

Mr. Emery Huse, *President*, Society of Motion Picture Engineers.

Dr. F. R. Watson, *President*, Acoustical Society of America.

Dr. Harvey Fletcher, Bell Telephone Laboratories, New York,  
N. Y.

**THURSDAY, MAY 8th**

**9:30 a.m. Projection Session; D. E. Hyndman, Chairman.**

Report of the Theater Engineering Committee; A. N. Goldsmith,  
*Chairman.*

*Projection Practice Symposium, prepared by the Projection Practice Sub-Committee  
of the Theater Engineering Committee*

"Projection Room Equipment Requirements;" J. J. Sefing.

"The Projection Room—Its Location and Its Contents;" J. R.  
Prater.

"Factors Affecting Sound Quality;" A. Goodman.

"A Suggested Clarification of Carbon Arc Terminology as Applied  
to the Motion Picture Industry;" H. G. MacPherson, National  
Carbon Co., Cleveland, Ohio.

"Improved Methods of Controlling Carbon Arc Positions;" D. J.  
Zaffarano, W. W. Lozier, and D. B. Joy, National Carbon Co.,  
Fostoria, Ohio.

"A New 13.6-Mm High-Intensity Projector Carbon;" W. W.  
Lozier and D. B. Joy, National Carbon Co., Fostoria, Ohio.



**2:00 p.m. General Session; A. C. Downes, *Chairman*.**

"The Subjective Sharpness of Simulated Television Images;" M. W. Baldwin, Jr., Bell Telephone Laboratories, New York, N. Y.

"A Compact Direct-Reading Reverberation Meter;" E. S. Seeley, Altec Service Corp., New York, N. Y.

"Solution of Acoustic Problems Encountered in Recording Sound for Motion Pictures;" W. L. Thayer, Paramount Pictures, Inc., Hollywood, Calif.

"Development and Current Uses of the Acoustic Envelope;" H. Burris-Meyer, Stevens Institute of Technology, Hoboken, N. J. (*Demonstration.*)

"Notes on the Mechanism of Disk Recording and Playback;" O. Kornei, Brush Development Co., Cleveland, Ohio.

"Analytic Treatment of Tracking Error and Notes on Optimum Pick-Up Design;" H. G. Baerwald, Brush Development Co., Cleveland, Ohio.

**Adjournment of the Convention.**

## HIGHLIGHTS OF THE CONVENTION

SAGAMORE HOTEL, ROCHESTER, N. Y.  
MAY 5-8, 1941

Variety of subject matter featured the 1941 Spring Convention just ended at Rochester. Summaries of a number of the presentations were published in the May JOURNAL and indicated a range of subjects including practically all the important aspects of motion picture engineering.

The Convention was marked also by very good attendance at all sessions, as well as at the social functions. The Wednesday morning session at the Eastman Theater attracted as many as 300 persons, and even at the closing session of the Convention on Thursday afternoon the attendance was in excess of 50 persons. The orchestra floor of the Eastman Theater was completely filled on the evening of the stereophonic demonstration.

The Monday morning session opened with the usual reports of officers and an address of welcome by President Huse. An outstanding presentation of the session was a description of the Visual Education Program at the University of Minnesota, by R. A. Kissack, illustrated by motion pictures produced by the Minnesota Visual Education Department for educational purposes. E. R. Morin of the Motion Picture Division of the Connecticut State Police described further work by the State of Connecticut in reducing fire hazards in motion picture theaters, referring particularly to the development of safety devices for air-conditioning equipment. Mr. J. A. Vickers of National Film Carriers, Inc., gave an interesting account of the complexities of transporting film to and from between exchanges and theaters throughout the country.

Two-hundred and eight members and guests of the Society attended the Informal Get-Together Luncheon held at noon on Monday, May 5th, at the Sagamore Hotel. Mr. Emery Huse, President of the Society, acting as master of ceremonies, introduced the Honorable S. B. Dickers, Mayor of the City of Rochester, who welcomed the members and guests to the City and invited them to take advantage of all the interesting features and attractions in the vicinity. Dr. F. R. Watson, President of the Acoustical Society of America, followed with a few brief words of pleasure for the coöperative relations existing between the SMPE and the Acoustical Society, particularly with reference to the joint sessions to be held on the following Wednesday. The proceedings were concluded by Dr. Howard Hanson, Director of the Eastman School of Music of the University of Rochester, who spoke interestingly and at some length on the relations between the technology of motion pictures and the musical art.

Monday afternoon was devoted to a group of papers on assorted subjects. Messrs. F. T. Bowditch, R. B. Dull, and H. G. MacPherson presented a paper on the characteristics of intermittent carbon arcs. Surge brilliancies much higher than can be continuously maintained on the same carbon are readily achieved, for instance, 1600 candles per sq-mm for a 7-mm carbon of the Suprex type. If the time between surges is so short that the arc stream does not have time to de-

ionize, no maintaining current at all is required between surges. The timing and duration of the pulses are controlled by electronic switching of half-cycle current surges from an a-c supply.

Properties of polished glass surfaces were discussed by Mr. Frank L. Jones of the Bausch & Lomb Optical Company, with particular reference to the formation of colored stains on the surface of dense lead or barium glasses exposed to the weather, in the formation of surface haze on lenses exposed to tropical humidity, and in the formation of silica low-reflection films on glass by chemical treatment.

Mr. W. Miller of the Vard Mechanical Laboratories, Pasadena, Calif., continued the subject in a paper on recent improvements in non-reflecting lens coatings, with special reference to the durability of the surface and the extent of reduction of the reflectivity.

Messrs. W. G. Hill and C. L. Schaefer of Agfa Ansco, and J. H. Chandler of the Eastman Kodak Company, presented papers dealing with theoretical considerations and methods of designing film sprockets, and the session closed with an extensive report of the Non-Theatrical Equipment Committee by J. A. Maurer, its Chairman. This report was prepared in response to a request from the Committee on Scientific Aids to Learning, of the National Research Council, and consists of two parts. Part I is a general discussion of the problems of selection and use of 16-mm motion picture equipment for educational institutions, including recommendations for such comparative tests of equipment as can be made without testing laboratory facilities. Part II consists of a set of detailed technical specifications defining acceptable performance of 16-mm projection equipment for educational purposes, these specifications being of such character that they can be interpreted and applied only by fully equipped testing laboratories. This report fills an urgent need in the industry and contains much material that has not heretofore been available.

The Monday evening session opened with the Report of the Standards Committee by the Chairman, D. B. Joy, and was followed by a symposium of three papers dealing with multi-speaker sound systems. H. I. Reiskind of the RCA Manufacturing Company presented a paper discussing the various types of reproducing systems employing multiple speakers demonstrated and used during the past few years. In addition, he analyzed the various requirements of such systems and the effects they are intended to produce. The following paper, by W. Garity and N. A. Hawkins of Walt Disney Studios, Burbank, Calif., described in particular the "Fantasound" system used in conjunction with Walt Disney's *Fantasia*. The final paper dealing with multi-speaker systems was presented by Nathan Levinson and L. T. Goldsmith of Warner Bros. First National Studios, Burbank, Calif., in which was described the "Vitasound" system recently developed by that studio.

As a concluding paper for the session, Messrs. J. O. Baker and R. O. Drew of RCA Manufacturing Company, presented a paper on new and old aspects of the origin of 96-cycle distortion, in which the work of previous investigations was reviewed and correlated with the results in an additional study made by the authors, on the disturbances caused by sprocket-hole modulation. It is concluded that the omission of sprocket-holes adjacent to the sound-track would completely eliminate 96-cycle distortion.



Outstanding among the papers presented at the session on Tuesday morning was a discussion of some recent advances in the theory of the photographic process, by Dr. C. E. K. Mees of the Eastman Kodak Company, Rochester. This presentation constituted a more or less popular discussion of recent advances in our knowledge of what happens when photographic materials are exposed and developed, the most recent advances in such knowledge having been provided by studies made with the aid of the electron microscope in photographing the silver grains in the photographic emulsion. The photomicrographic results achieved with the electron-microscope have caused photographic chemists and physicists to revise a number of ideas previously held regarding photographic processes, and the new technic of investigation will doubtless lead to a more thorough understanding of what goes on in the photographic process.

Other interesting papers of the Tuesday morning session included one on high-fidelity head-phones by L. J. Anderson of the RCA Manufacturing Company; one on new gadgets for the film laboratory, with special reference to an air squeegee for use in a continuous film processing machine, by B. Robinson and M. Leshing, of Twentieth Century-Fox Film Corp., Hollywood, Calif.; and a report on the activities of the Inter-Society Color Council by Ralph M. Evans, Chairman of the SMPE Delegates to the Council.

Time was devoted during the morning to a brief business session, at which Mr. A. S. Howell, a pioneer in the motion picture industry and one of the founders of the Bell & Howell Company of Chicago, was elected Honorary Member of the Society. In addition, action was taken upon the amendments of the By-Laws published in the May, 1941, JOURNAL (p. 586), the vote on these amendments indicating unanimous approval.

The evening of Tuesday, May 6th, was devoted to the 49th Semi-Annual Banquet and Dance of the Society at the Sagamore Hotel. The evening was given over completely to dancing and entertainment.

The entire day of Wednesday, May 7th, was devoted to three joint meetings of the Acoustical Society of America and the Society of Motion Picture Engineers, the morning and evening sessions being held in the Eastman Theater, and the afternoon session at the Sagamore Hotel. These sessions were devoted to a very detailed and complete description of the stereophonic sound-film system developed by the Bell Telephone Laboratories and presented by a number of engineers of that organization. The symposium consisted of a group of seven papers, presented at the morning and afternoon sessions, including a technical demonstration in the morning session.

In the evening a more general and popular demonstration of the equipment was given in the Eastman Theater, to which were invited not only the members and guests of the SMPE and the Acoustical Society, but also a large number of members of the Eastman School of Music and the Rochester Musical Society. It is estimated that approximately 2000 persons were present. The proceedings were opened by Dr. Howard Hanson, Director of the Eastman School of Music, who acted as Chairman, introducing Mr. Emery Huse, President of the SMPE, and Dr. F. R. Watson, President of the Acoustical Society, both of whom addressed words of welcome to the delegates and appreciation to the Bell Telephone Laboratories for making this demonstration available.

The program was conducted by Dr. Harvey Fletcher, Director of Physical



Research of the Bell Telephone Laboratories, and consisted of a number of selections specially chosen to illustrate the stereophonic effects, the frequency or pitch range of the system, the naturalness of reproduction, the dynamic range, and the effects resulting from the enhancement feature of the system.

During the Wednesday afternoon session, there were two additional presentations apart from the papers on the stereophonic sound-film system. The first of these was by J. A. Norling of the Loucks & Norling Co., New York, N. Y., and described recent progress in three-dimensional photography. Accompanying the presentation was a demonstration of still pictures projected in relief upon the screen by the vectograph method. The other presentation was the projection of a film showing motion pictures of solar prominences, taken by Dr. R. R. McMath at the McMath-Hulbert Observatory, Pontiac, Mich. The presentation included a brief description of the camera mechanism used for taking the pictures, the time range of which extended from about 30 seconds per exposure to perhaps several hours. This work has resulted in a revision of many theories pertaining to the origin, nature, and motions of the solar prominences.

The morning session of Thursday, May 8th, was devoted to projection, and opened with the Report of the Theater Engineering Committee, Dr. Alfred N. Goldsmith, Chairman, followed by three general papers on projection by members of the Projection Practice Sub-Committee of the Theater Engineering Committee. In addition were three papers by Messrs. H. G. MacPherson; D. J. Zaffarano, W. W. Lozier, and D. B. Joy; and W. W. Lozier and D. B. Joy; all of the National Carbon Co., Cleveland and Fostoria, Ohio. These papers were devoted, respectively, to the subjects of carbon arc terminology as applied to the motion picture industry, methods of controlling arc positions, and a new 13.6-mm high-intensity projector carbon.

The afternoon was devoted to six interesting presentations, three dealing with sound and acoustics, two with disk recording, and one with the sharpness of television images. Mr. H. Burris-Meyer of the Stevens Institute of Technology, Hoboken, N. J., discussed the development and uses of the "acoustic envelope," a method providing for a singer or an actor an acoustic effect around him similar to what he experiences when performing in a more or less reverberant room or enclosure. The "envelope" of sound is made audible to the performer only and not to the audience. Mr. E. S. Seeley of Altec Service Corp., New York, described a compact direct-reading reverberation meter, and W. L. Thayer of Paramount Pictures, Inc., Hollywood, Calif., discussed at some length a number of the acoustical problems encountered in recording on motion picture sound-stages. Messrs. O. Kornei and H. G. Baerwald of the Brush Development Company, Cleveland, Ohio, presented mathematical analyses of various types of distortion occurring in pick-ups for disk recording.

#### ACKNOWLEDGMENTS

The Society wishes to acknowledge its gratitude to the large number of persons and companies who collaborated in providing the various facilities for the Convention.

Acknowledgment is due also to Loew's Theaters, Inc., and Monroe Amusements, Inc., for passes issued to the Convention delegates to the *Rochester, Palace, Regent*, and *Century* Theaters.

## SOCIETY ANNOUNCEMENTS

### 1941 FALL CONVENTION

The Spring Convention at Rochester having just ended, the Convention Committee under the Chairmanship of W. C. Kunzmann, *Convention Vice-President*, has begun to make preparations for the approaching Fall Convention to be held at the Hotel Pennsylvania, New York, N. Y., October 20th-23rd, inclusive. Members who contemplate presentation of papers at the Fall Convention should communicate with the Editor of the JOURNAL as early as possible.

The Progress and Journal Awards will be presented at the banquet on Wednesday, October 22nd. This banquet will be the Fiftieth Semi-Annual Banquet of the Society, commemorating twenty-five years of active service of the Society to the motion picture industry.

### NOMINATION OF OFFICERS AND GOVERNORS FOR 1942

At the meeting of the Board of Governors held at Rochester on May 4, 1941, the following Committee was appointed, in accordance with the Administrative Practices of the Society, to submit nominations for 1942. The Nominating Committee is as follows:

#### *Nominating Committee*

	H. GRIFFIN, <i>Chairman</i>	
M. C. BATSEL	J. FRANK, JR.	K. F. MORGAN
E. K. CARVER	BARTON KREUZER	H. G. TASKER
A. C. DOWNES		E. A. WILLIFORD

Officers and Governors whose terms expire December 31, 1941, are as follows:

Engineering Vice-President	D. E. HYNDMAN
Financial Vice-President	ARTHUR S. DICKINSON
Secretary	PAUL J. LARSEN
Treasurer	GEORGE FRIEDL, JR.
Governor	ALFRED N. GOLDSMITH
Governor	ARTHUR C. HARDY
Governor	T. E. SHEA

All the above-mentioned offices are for two-year terms, except those of the Secretary and Treasurer, which are for one-year terms.

Members of the Society are requested to submit their suggestions for nominations to the Chairman of the Nominating Committee before July 1st. The next meeting of the Board of Governors will be held on July 24th, at which time the Nominating Committee must render its report, wherefor suggestions and proposals from the membership of the Society must be received in time for consideration.

**HONORARY MEMBERSHIP TO A. S. HOWELL**

At the meeting of the Board of Governors held at Rochester, N. Y., May 4th, the name of Mr. A. S. Howell was proposed for Honorary Membership in the Society. Upon approval by the Board of Governors the proposal was placed before the general meeting of the Society held at the Rochester Convention on the morning of May 6th, and was unanimously approved.

The Society is therefore highly pleased to add Mr. Howell's name to the list of Honorary Members.

The granting of Honorary Membership in the Society of Motion Picture Engineers is a distinction given to pioneers who have contributed inventions of basic importance to the motion picture industry and have perfected their contributions to a useful stage.

A certificate of Honorary Membership, signed by the members of the Board of of Governors, will be presented to Mr. Howell in the near future.

**AMENDMENTS OF THE BY-LAWS**

In the May, 1941, issue of the JOURNAL on p. 586 were published several amendments proposed for By-Laws IV, VII, and XI. At the general meeting of the Society held at the Rochester Convention on May 6th, these amendments were approved.

**ADMISSIONS COMMITTEE**

At a recent meeting of the Admissions Committee, the following applicants for membership were admitted into the society in the Associate grade:

ALMQUIST, P. B.

2041 Thayer Ave.,

Los Angeles, Calif.

CALLAWAY, A. S.

2356—40th St., N.W.,

Washington, D. C.

COBB, D. H.

10462 Wilkins Ave.,

West Los Angeles, Calif.

DAMON, J. L.

1031 South Broadway

Los Angeles, Calif.

FISHER, ROY J.

327 Lexington Ave.,

Rochester, N. Y.

FRIEND, B.

214 Riverside Drive,

New York, N. Y.

GEIS, CHARLES C.

5939 N. Forest Glen Ave.,

Chicago, Ill.

GOODFELLOW, C. E.

4133 Jasmine Ave.,

Culver City, Calif.

HEPPBERGER, C. E.

632 E. 84th St.,

Chicago, Ill.

KING, S. G.

1827 Estes Ave.,

Chicago, Ill.

KNOX, H. E.

6823 Santa Monica Blvd.,

Hollywood, Calif.

MCILROY, WALTER

1910 Ferry St.,

Easton, Pa.

ROBERTSON, JACK

Extension Division,

University of Calif.,

Berkeley, Calif.

RUSSELL, R. W.  
856 South Norton Ave.,  
Los Angeles, Calif.

SILBERSTEIN, A. H.  
956 Simpson St.,  
Bronx, N. Y.

STOTT, J. G.  
Eastman Kodak Co.,  
350 Madison Ave.,  
New York, N. Y.

TALOTT, G. J.  
Third Street,  
Cementon, Pa.

In addition, the following applicants have been admitted to the Active Grade:

FERNSTROM, C. E.  
67 Bay Road,  
Sharon, Mass.

LOZIER, W. W.  
National Carbon Co.,  
Fostoria, Ohio

MERTZ, PIERRE  
Bell Telephone Laboratories, Inc.,  
463 West St.,  
New York, N. Y.

RODGERS, ALSTON  
Lamp Department,  
General Electric Co.,  
601 W. 5th St.,  
Los Angeles, Calif.

SNODY, A. P.  
258 Lee Ave.,  
Yonkers, N. Y.

TYSON, A. S.  
1051 S. Stanley St.  
Los Angeles, Calif.

The following member has been transferred from Associate to Active Grade:

DATSHKOVSKY, JOES  
RCA Victor Mexicana S. A.,  
Calzada Villalongin No. 196,  
Mexico, D. F.



**JOURNAL**  
**OF THE SOCIETY OF**  
**MOTION PICTURE ENGINEERS**



**AUTHOR AND CLASSIFIED**  
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